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# ELECTRONIC EQUIPMENT

# VS.

# THE SPACE ENVIRONMENT

## A PARTIALLY ANNOTATED BIBLIOGRAPHY

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Prepared by

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## ABSTRACT

A bibliography is presented on the subject of the space environment and its effect on electronic equipment. Consisting of 357 references, the subject matter is broken down into the following categories: A. Radiation Effects; B. Micrometeorites; C. Temperature; D. Vacuum; E. General. Most of the references cover the years 1958-1962, although there are some cited which were published prior to 1958. The references are arranged alphabetically by source, report number, author, and date respectively. Author, corporate source and periodical, and subject indexes follow.

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# INTRODUCTION

With each step further into space new demands, new criteria, new limits, are placed upon the electronic equipment which will be used in later probes. This bibliography attempts to bring together the main categories of the space environment and present information about each constituent. It is intended to be used as a basic guide to research, design, and related fields where space environmental effects are of vital importance

The report, consisting of 357 references, is divided into the following categories:

A. Radiation Effects

B. Micrometeorites

C. Temperature

D. Vacuum

E. General

The wealth of information on the subject of Radiation Effects has necessitated the breaking down of this category into the following sub-categories:

1. Electron Tubes

2. Hydraulic Fluids and Lubricants

3. Materials

4. Plastics and Elastomers

5. Semiconductors

6. Solar Cells

7. General

The references, within each category, are arranged alphabetically by source, report number, author, and date respectively. Following the references are three complete indexes: Author, Corporate Source and Periodical, and Subject.

SECTION A

## Radiation Effects

SECTION A

## Radiation Effects

### 1. Electron Tubes

1. VARIATION DE COLORATION ET DE TRANSLUCIDITÉ DES VERRES, PAR SUITE DE LEUR IRRADIATION PAR DES RAYONNEMENTS $\gamma$ (SOURCE DE $^{60}Co$) ET DE LEUR IRRADIATION DANS UN REACTEUR NUCLÉAIRE (OB IZMENENIYA TSVETA I PROZRACHNOSTI STEKOL PRI OBLUCHENIYA IKH $\gamma$-LUCHAMI ISTOCHNIKA $Co^{60}$ I V YADERNOM REAKTORE) (COLOR AND TRANSPARENCY CHANGES OF GLASSES EXPOSED TO $\gamma$-RAYS FROM $Co^{60}$ AND TO NUCLEAR REACTOR RAYS). S. M. Brekhovskikh. (Atomnaya Energiya, USSR, Vol. 8, No. 1, 1960, pp. 37-43) In Russian (CEA Translation No. R 1395, 15 September 1961, 21 p., 5 refs.) (Order from OTS or SLA $2.60) In French with Russian Text Included

2. EFFECT OF NUCLEAR RADIATION OF GLASS. W. C. Riley, W. G. Coppins and W. H. Duckworth. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Technical Memorandum No. 9, 30 November 1958, 24 refs., 162 p.) AD 207 701

Currently, the primary interest in glass for nuclear-powered aircraft applications is in optical systems, electron tubes, and dosimetry. Coloration is undesirable in optical systems and may render them useless. Radiation damage to glass has resulted in mechanical failure of electron tubes. The dosimeter application, on the other hand, depends on irradiation-induced coloration of glass.

The purpose of this technical memorandum is to present available information on radiation effects in glass and to recommend areas that require further investigation.

3. EFFECT OF NUCLEAR RADIATION ON ELECTRON TUBES AND TUBE MATERIALS. W. E. Chapin. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Report No. 14, 15 February 1961, 36 p.) AD-252 607

4. PULSED GAMMA INITIATION OF BREAKDOWN IN GAS TUBES. Alan J. Talbert and Neil D. Wilkin. (Diamond Ordnance Fuze Laboratories, Washington, D. C., Project No. 54050, DOFL Report No. TR-961, 10 July 1961, 24 p.) AD-260 821

Miniature cold-cathode diodes of the GE XD series were subjected to pulses of gamma radiation from the electron linear-acceleration (linac) facility to determine under laboratory conditions the values of gamma dose and dose rate required to initiate breakdown in the diodes at different bias voltages. Elapsed time between gamma pulse onset and diode breakdown was measured. Curves are presented of the relationship between gamma dose and diode breakdown as a function of diode voltage. The data are compared with similar data taken in Operation Plumbbob (Nevada, 1957). The results show that each of the diodes tested is applicable to nuclear-proofing devices with corresponding operating voltage range.

5. LITERATURE SURVEY ON THE EFFECTS OF RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Semiannual Report, 1 February-30 November 1957)

6. UNCLASSIFIED LITERATURE SURVEY ON THE EFFECTS OF NUCLEAR RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, DA-36-039-SC-73146, Report No. 8, 1 March-1 June 1959)

Ceramic tubes when exposed to a total dose of $10^{19}$ nvt have a residual activity of two weeks exceeding 100 R/hr at the surface. The effect of this high residual activity in relation to tube life is discussed.

The effect of nuclear radiation on subminiature tubes, thin films, magnetic materials, and secondary emission is discussd.

7. LITERATURE SURVEY ON THE EFFECTS OF NUCLEAR RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, Quarterly Report No. 9, 31 August 1959, 11 p.) AD-228 813

8. LITERATURE SURVEY ON THE EFFECTS OF RADIATION ON ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, Quarterly Report No. 10, November 1959) AD-232 188

9. LITERATURE SURVEY OF THE EFFECTS OF NUCLEAR RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, Quarterly Progress Report No. 11, February 1960, 20 p.) AD-236 131

10. UNCLASSIFIED LITERATURE SURVEY ON THE EFFECTS OF NUCLEAR RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, Quarterly Progress Report No. 12, May 1960)

11. UNCLASSIFIED LITERATURE SURVEY ON EFFECTS OF NUCLEAR RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, Quarterly Progress Report No. 14, 31 October 1960, 43 p.) AD-252 708

12. UNCLASSIFIED LITERATURE SURVEY ON EFFECTS OF NUCLEAR RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, Report No. 5735-1, 31 January 1961, 18 p.)

13. UNCLASSIFIED LITERATURE SURVEY ON EFFECTS OF NUCLEAR RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, Report No. 5735-2, April 1961, 19 p.) AD-259 700

14. UNCLASSIFIED LITERATURE SURVEY ON EFFECTS OF NUCLEAR RADIATION TO ELECTRON TUBE MATERIALS. E. R. Johnson. (Stevens Institute of Technology, Hoboken, New Jersey, Report No. 5735-3, 31 July 1961, 16 p.) AD-265 357

15. DEVELOPMENT AND EVALUATION OF ELECTRON TUBE GLASSES RESISTANT TO RADIATION DAMAGE. R. Spencer. (Tung-Sol Electric, Inc., Chatham Electronics, Livingston, New Jersey, Second Semiannual Progress Report, 1 May 1960) AD-243 561

SECTION A

Radiation Effects

2. Hydraulic Fluids and Lubricants

16. EFFECT OF NUCLEAR RADIATION ON THE PERFORMANCE OF A HYDRAULIC FLIGHT-CONTROL SYSTEM. Raymond E. Hess and R. F. Badertscher. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus 1, Ohio, AF 33(616)-6564, REIC Memorandum 18, 15 June 1959, 14 p.)

In the nuclear-radiation-effects program to date a rather strong emphasis has been placed on components and materials. The component, being a fundamental building block, must be available before subsystems and systems can be physically realized. Since the design and testing of components or elementary subsystems for nuclear-powered aircraft is understandable. Until such time as proven components are available and system problems supersede component difficulties, this emphasis must continue. As an initial step toward anticipating the development through the subsystem, system, and weapon-system phases, the gross effect of nuclear radiation on a hydraulic flight-control system has been studied.

17. EFFECT OF NUCLEAR RADIATION ON HYDRAULIC, PNEUMATIC, AND MECHANICAL SYSTEMS FOR SUBSONIC, TRANSONIC, AND LOW-SUPERSONIC SPEED AIRCRAFT. Raymond E. Hess and Wilbur A. Spraker. (Battelle Memorial Institute, Radiation Effects Information Center, Contract AF 33(616)-5171, REIC Report No. 1-C and Addendum, SECRET RESTRICTED DATA)

This report deals exclusively with problems representative of subsonic, transonic, and low-supersonic speed aircraft of relatively conventional configurations powered by nuclear turbojets. Feasibility studies of the utilization of nuclear ram-jet and rocket power plants in various weapon systems have not indicated promising possibilities in higher performance vehicles.

The purpose of the addendum is to bring the material presented in the basic report up to date by discussing developments in airborne hydraulic, pneumatic, and mechanical systems which have come to the attention of REIC since the publication of the earlier report.

18. EFFECT OF NUCLEAR RADIATION ON LUBRICANTS AND HYDRAULIC FLUIDS (FIRST ADDENDUM). S. L. Cosgrove. (Battelle Memorial Institute, Radiation Effects Information Center, REIC Report No. 4, 31 March 1959, 51 p.) Ad 210 760

Radiation-resistant gas-turbine-lubricant development during the past year has centered around the expanded study of polyphenyl ethers and alkylated aromatic ethers. Meta-linked polyphenyl ethers (unhibited) show promise for use in the 0 to 700° F range and at exposures up to $1 \times 10^{11}$ ergs $g^{-1}$ (C). Alkylated diphenyl ethers and diaryl alkanes show the most promise for use in conventional hydraulic systems under irradiation conditions.

19. EFFECTS OF GAMMA RADIATION ON ELASTOMERS, SEALANTS, STRUCTURAL ADHESIVES, LUBRICANTS AND GREASES. Chester J. DeZeih. (Boeing Airplane Company, Seattle, Washington, Report D2-2449)

20. EFFECT OF NUCLEAR RADIATION OF GYRO FLUIDS. Howard L. Steele. (Boeing Company, Seattle, Washington, Document No. D2-2753, 21 October 1958, 12 p.) AD-266 099

Typical fluids used to float the gyro in new low-drift gyros for inertial guidance are affected by nuclear radiation. Dow Corning Silicone DC-200 (200 and 350 centistoke viscosity) and Hooker Fluorolubes grades FS, S, and FC 43 were exposed either to Cobalt-60 gamma rays at the Boeing gamma facility or to a fission spectrum of pulsed neutrons at the Los Alamos Godiva facility. The viscosity was the most sensitive property measured and the denser fluid showed the greatest change. A 10% decrease occurred in 350 centistoke DC-200 at a dose of 4 x 10 to the 15th power gammas/sq cm or 12.5 x 10 to the 13th power neutrons/sq cm. The reduction in density at these doses was not much more than the experimental error (about 1%). Changes in the IR transmission spectra were barely greater than the experimental error for doses below those which produced a gel. If the density changes noted occurred in a short time, the gyro would not be able to take the change into account and drift greater than specified would result.

21. GAMMA IRRADIATION OF AN ELECTRO-HYDRAULIC SERVO TEST LOOP USING ORONITE 8515 HYDRAULIC FLUID. A. MacCullen. (Lockheed Aircraft Corporation, Nuclear Products, AF 33(600)-38947, August 1958-June 1959, January 1960, WADC TR 59-592)

22. RADIATION STABILITY OF SILICONE GREASES. D. J. Fischer, J. F. Zack, Jr. and E. L. Warrick. (Lubrication Engineering, Vol. 15, October 1959, pp. 407-409)

Static tests were conducted at 38 C on commercial and experimental greases to show their probable limits of radiation stability.

23. SOLID FILM LUBRICANTS FOR HIGH TEMPERATURE NUCLEAR ENVIRONMENTS. Bruce Daniel. (Midwest Research Institute, Kansas City, Missouri, Contract AF 33(616)-6728, Report on ANP Airframe and General Support, 1 June 1959-1 June 1961, September 1961, 43 p., 10 refs., WADD TR 60-283, Part 2) AD-269 429

The effect of gamma radiation on PbO:B2O3 and MoS2:NaOSiO2 films was studied. Within experimental variation no effect on wear-life could be measured. At least one specimen of each irradiated film had an unusually long wear-life indicating that if the gamma dose reduces wear-life, the effect is probably not severe. A new friction machine was constructed for evaluating solid lubricant films operating in a gamma flux. The films, coated on plain spherical bearings, were run in oscillatory motion. The effect of gamma doses on wear-life on MoS2:Na2B4O7 and Lubricant A in dioxane could not be measured within experimental variation. The effect of load, temperature, and pigment-to-adhesive ratio on wear-life was studied also for PbS:MoS2 and MoS2:B2O3. Experiments on solid lubricant pellets showed that a gamma dose of 0.878 x 10 to the 12th power erg/gC increases friction. No change in lattice spacings was found.

24. DEVELOPING RADIATION-RESISTANT LUBRICANTS. H. C. O'Conner. (Nuclear Power, Vol. 4, August 1959, pp. 88-89)

High flux tests; range of oils and greases developed; applications in Bradwell machinery.

25. NUCLEAR RADIATION RESISTANT GYROSCOPE BEARING LUBRICANTS AND FLOTATION MEDIA. Frank R. Callihan, Robert A. Falk and others. (Sperry Gyroscope Company, Great Neck, New York, Contract AF 33(616)-6187, Report on ANP Airframe and General Support, 16 November 1959-31 October 1960, March 1961, 118 p., 208 refs., WADD TR 60-753, Part 1) AD-263 456*

*NO AUTOMATIC RELEASE TO FOREIGN NATIONALS.

Available data concerning various classes of organic liquids are presented and discussed with respect to radiation resistance and potential application as gyro lubricants and flotation fluids. A number of these fluids were selected as lubricant candidates and additional evaluation performed. Suitable radiation resistant flotation fluids are not currently available: therefore, a synthesis program was initiated to prepare such materials. The study and evaluation of existing lubricants and synthesis of flotation fluids are reported.

26. NUCLEAR RADIATION RESISTANT HIGH TEMPERATURE LUBRICANTS.
C. L. Mahoney, E. R. Barnum, W. S. Saari, K. J. Sax and W. W. Kerlin, Shell Development Company. (U. S. Air Force, Wright Air Development Center, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, WADC Technical Report 59-173, September 1959, 123 p., 18 refs.)

Polyphenyl ethers are very promising materials for further development as radiation-resistant high-temperature lubricants. The unsubstituted polyphenyl ethers are far more stable than presently-used lubricants and can be classified with the most resistant types of aromatic compounds (polyphenyls, aromatic silanes, etc.) with respect to radiation, oxidation and thermal stability. Furthermore, these ethers have much lower melting points, better physical properties and much better lubrication characteristics than the other aromatic materials. Unsubstituted meta-linked polyphenyl ethers having pour points of 5°F and 40°F have been prepared. Initial thermal decomposition temperatures of these ethers are 830°F or higher.

27. DEVELOPMENT OF NUCLEAR RADIATION-RESISTANT HYDRAULIC FLUIDS.
N. W. Furby, M. A. Pino, S. R. Calish and D. R. Wilgus, California Research Corporation. (U. S. Air Force, Wright Air Development Center, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, WADC Technical Report 59-252, October 1959, 151 p.)

Synthesis work during this contract period had several parts. A synthetic base fluid, isopropyl-1,9-diphenylnonane, having an excellent combination of viscosity-temperature properties and stability against the common types of degradation, was developed. Gallon quantities of this material were prepared for formulation studies and evaluation tests. Various polyalkylaromatics were synthesized for evaluation as viscosity-temperature improvers. A large laboratory batch of the $C_{14}$-$_{16}$-alkyl diphenyl ether-p-xylylene copolymer was prepared for use in the final fluid formulation, CALRESEARCH 59R-439. New leads, related to the in situ formation of polymeric materials in $\alpha,\omega$-diarylalkanes by treating with aluminum chloride, may make possible the development of superior fluids. This opens a fertile field for future research.

SECTION A

Radiation Effects

**3. Materials**

28. MATERIALS IN SPACE. Frederick L. Bagby, Battelle Memorial Institute, Columbus, Ohio. (Advances in Space Science, Volume II, Academic Press, New York, 1960, pp. 143-213)

Discusses selection criteria, applications, and future outlook of materials for high temperature service, lightweight pressure vessels, mechanical elements and devices, thermomechanical power systems, solid state electronic devices, instrumentation, and personnel equipment.

29. SURFACE EFFECTS ON MATERIALS IN NEAR SPACE. Francis J. Clauss, Lockheed Aircraft Corporation, Missile and Space Division, Van Nuys, California. (Aero/Space Engineering, Vol. 19, October 1960, pp. 16-19+)

Materials for spacecraft are reviewed from the standpoint of resistance to radiation, erosion, and ability to lubricate and prevent seizure.

30. NUCLEAR EFFECTS ON MATERIALS. (Aircraft and Missiles, Vol. 2, December 1959, pp. 22-24)

Brief review of gamma ray and fast neutron irradiation effects.

31. COMMENTS ON BEHAVIOR OF MATERIALS IN SPACE ENVIRONMENTS. B. Paul. (American Rocket Society Journal, Vol. 32, July 1962, p. 1117)

Brief discussion of a previous study by Jaffe and Rittenhouse of sublimation from materials in a high vacuum.

32. NEUTRON EFFECTS ON FERRITES. N. M. Omelyanovskaya. (Atomnaya Energiya, Vol. 7, 1959, p. 66)

Russian observations of the behavior of ferrites as memory elements in electromagnetic devices in thermal-neutron fields appear to confirm comparable U. S. results, although their integrated flux was less by a factor of ten. Ferrites were exposed in a flux of $1.5 \times 10^{13}$ n/cm$^2$/sec to integrated fluxes of $2.15 \times 10^{17}$ and $6.5 \times 10^{17}$ n/cm$^2$. Radiation-induced heating caused distortion of the hysteresis loop, as confirmed by control tests at 20$^\circ$-58.8$^\circ$C in the absence of radiation, while magnetic properties were independent of the integrated flux. However, loop rectangularity was poorer for the controls. The author suggests this difference may be due to the ordering of the ferrite lattice in the thermal-neutron flux, the mobility of the radiation-induced vacancies and counteraction of the temperature effects by interstitial atoms. Thus, he recommends that ferritic memory elements exposed to neutron and gamma fluxes higher than $5\text{-}50 \times 10^{11}$ n/cm$^2$/sec be provided with an automatic current-regulating device or cooling apparatus.

33. EFFECT OF NUCLEAR RADIATION ON ELECTRONIC TRANSFORMERS AND TRANSFORMER MATERIALS. J. F. Hansen. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus 1, Ohio, AF 33(616)-5171, Technical Memorandum No. 7, 30 November 1958, 4 p., 5 refs.)

This memorandum presents a summary of the information available in the Radiation Effects Information Center files on the effects of nuclear radiation on transformers and transformer materials. Recommendations regarding materials for transformer construction are also presented.

Investigations of radiation effects on transformers and transformer materials have been made by Convair, Division of General Dynamics Corporation, Fort Worth, Texas; General Electric Company; Admiral Corporation; and others.

34. SPACE RADIATION AND ITS EFFECTS ON MATERIALS. (Battelle Memorial Institute, Columbus, Ohio, REIC Memo. No. 21, June 1961) AD-261 277

35. EFFECTS ON MATERIALS BY NUCLEAR RADIATION (MATERIALBEEINFLUSSUNG DURCH KERNSTRAHLUNG). Gerald Reinsmith. (Bitumen, Teere, Asphalte, Peche, Vol. 10, No. 8, August 1959, pp. 295-296) In German

During nuclear fissions, approximately 10% of the liberated energy is released in the form of fission products, $\alpha$ and $\beta$ particles, gamma-rays and neutrons. Such materials as offer the highest resistance to these products are metals, ceramic substances, polysilanes, polyesters, phenol resins and epoxide phenol plastics. The substances rapidly attacked are fats, lubricants, hydraulic oils, natural and synthetic rubber and textiles.

36. EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC MATERIALS. V. R. Honnold and C. W. Perkins, Hughes Aircraft Company, Ground Systems Group, Fullerton, California. (Electronic Industries, Vol. 21, No. 2, February 1962, pp. 99-101, 15 refs.)

This is the second article in a planned series about pulsed nuclear radiation effects. Here it is learned how pulsed radiation affects insulating materials, metals, semiconductor materials, gases, and other electronic materials as an aid in designing radiation-proof equipment.

37. RADIATION DAMAGE TO NONMETALLIC MATERIAL. V. P. Calkins. (General Electric Company, ANPD, Cincinnati, Ohio, APEX 167, 11th Edition) AD-93 441

38. EFFECTS OF RADIATION ON MATERIALS. J. J. Harwood, U. S. Office of Naval Research; Henry H. Hausner, The Martin Company; J. G. Morse, The Martin Company, Nuclear Division; and W. G. Rauch, Office of Naval Research; Editors. (Reinhold Publishing Corporation, New York, 1958, 355 p. Bibliog.)

Contents: Defects in solids and current concepts of radiation effects, G. J. Dienes. Experimental approaches to radiation studies--radiation sources and dosimetry, J. C. Wilson. Radiation effects on physical and metallurgical properties of metals and alloys, E. S. Billington. Influence of radiation upon corrosion behavior and surface properties of metals and alloys, M. Simnad. Effects of radiation on electronic and optical properties of inorganic dielectric materials, R. Smoluchowski. Effects of radiation on semiconductors, H. Y. Fan and K. Lark-Horovitz. Cores, liquid coolants and control rods, C. E. Weber. Moderators, shielding and auxiliary equipment, G. R. Hennig. Experimental techniquez and current concepts--organic substances, M. Burton. Effects of radiation on behavior and properties of polymers, A. Charlesby. Radiation-induced graft copolymerization, A. J. Restaino. Bibliography "Effect of irradiation on solids," H. Friedemann.

39. EFFECTS OF VAN ALLEN BELT RADIATION ON MATERIAL. R. S. Shane. (IRE International Convention Record, Vol. 9, Part 5, 1961, pp. 129-138)

On the basis of experience from nuclear fission experiments it is concluded that many materials used in electronic equipment would deteriorate markedly if exposed to the radiation expected in the Van Allen belt. The greatest damage would probably be due to proton bombardment of plastic materials which could result in seriously worsened insulation properties, and chemical breakdown leading to the evolution of corrosive substances. The most sensitive components are likely to be solid state devices and capacitors. Proposals are made for a testing routine for potential components for use in satellites. Tables are given summarizing present knowledge in this field.

40. RADIATION EFFECTS CONSIDERATIONS ON MATERIALS IN CRYOGENIC SYSTEMS OF NUCLEAR ROCKETS. J. W. Gordon. (IRE Transactions on Nuclear Science, Vol. NS-9, No. 1, January 1962, pp. 299-302)

Sealing materials, lubricants, thermal insulation, and structural materials are discussed with respect to radiation stability. Some experimental data on the effects of simultaneous exposure of metals to nuclear radiation and cryogenic temperatures are also presented.

41. STUDY OF EFFECT OF HIGH-INTENSITY PULSED NUCLEAR RADIATION ON ELECTRONIC PARTS AND MATERIALS (SCORRE). (IBM Corporation, Owego, New York, Contract DA 36-039-sc-85395, Quarterly Progress Report No. 5, 1 July-30 September 1961, 30 September 1961, 11 p.) AD-267 398*

*No automatic release to Foreign Nationals.

Radiation tests scheduled to be conducted at the Sandia Pulsed Reactor Facility in November 1961 are described. The electrical behavior of glass-dielectric capacitors was to be observed during the bursts. The Sandia Pulsed Reactor was to be used as the radiation source.

42. HOW RADIATION AFFECTS ENGINEERING MATERIALS. Richard E. Bowman. (Materials in Design Engineering, Vol. 52, July 1960, pp. 119-134)

Gamma rays and neutrons cause property changes in the environment. Structural metals generally have best radiation resistance. Inorganic materials show many changes in physical and mechanical properties. Elastomers vary widely in radiation resistance. Plastics generally have equal or better radiation resistance than elastomers. Organic fluids can have composition adjusted to provide compromise of properties.

43. MECHANICAL BEHAVIOR OF MATERIALS. R. T. Ault, I. K. Ebcioglu, D. M. Forney, Jr., J. A. Roberson and others. (U. S. Air Force, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, ASD Technical Report 61-322, July 1961, pp. 845-882) also (Materials Symposium, Phoenix, Arizona, 13-15 September 1961) AD 264 193

44. GAMMA RADIATION EFFECT ON THE ELECTRICAL CONDUCTIVITY OF MATERIALS. W. F. Pfeiffer. (U. S. Air Force Institute of Technology, Air University, GNE-59-12, March 1959) AD 215 599

45. NUCLEAR RADIATION EFFECTS ON ELECTRONIC MATERIALS AND COMPONENTS. (U. S. Signal Corps Engineering Laboratories, Dielectric Materials Section, Materials Branch, Electronic Parts and Materials Division, Components Department, Fort Monmouth, New Jersey, Information Bulletin No. 268, 31 January 1957)

SECTION A

Radiation Effects

4. Plastics and Elastomers

47. THERMAL AND GAMMA RADIATION BEHAVIOR OF A NEW HIGH TEMPERATURE ORGANIC FIBER. C. O. Little, Jr. (Aeronautical Systems Division, Directorate of Materials and Processes, Wright-Patterson Air Force Base, Ohio, Project No. 7320, Report on Fibrous Materials for Decelerators and Structures, May 1958-September 1960, June 1961, 39 p., WADD TN 60-299) AD-266 328

This research study involves a new temperature resistant experimental organic fiber known as HT-1, whose chemical structure is a departure from the conventional polyamide and polyesters. The behavior of this fiber during and after exposure to temperatures up to 650 F alone and in conjunction with gamma radiation indicates that a major breakthrough in organic fiber technology was achieved. Exposure to ionized radiation does not affect the tensile or elongation of HT-1 yarn. Tensile retention at 500 F is increased from 84.8 to 91.6% after combined thermalionized radiation exposure; at 600 F, tensile retention is increased from 52.2% to 78.2%. The superior behavior of HT-1 can be exploited to affect the greatest over-all advance in temperature resistant fiberology through utilization in aircraft and personnel deceleration systems; missile and booster recovery systems; aircraft tires, ducting, fuel diaphrams and expulsion bags; reinforcement for ablating plastics for re-entry heat shields, and other hyperthermal applications.

48. THERMAL IRRADIATION OF PLASTIC MATERIALS. Herbert S. Schwartz and Rex W. Farmer. (Aeronautical Systems Division, Directorate of Materials and Processes, Wright-Patterson Air Force Base, Ohio, Project 7340, August 1961, 71 p., 28 refs., WADD TR 60-647) AD-267 578

Degradation and short time rupture of several reinforced plastics and structural adhesives were investigated during intense radiant heating. Thermal response was found to be a function of certain materials properties, stress conditions and environmental parameters. Plastic specimens were preloaded in tension and irradiated in an arc-imaging furnace. Time to rupture was a function of: resin and reinforcement type, spectral characteristics and thickness of the material, angle, and magnitude of the applied static stress, and radiant flux density. Rupture times ranging from 0.5 to 45 sec were observed for applied stresses of 20 to 70% of the ultimate room temperature strength and radiant flux densities of 1 to 25 Cal/sq cm-sec. An exploratory study was made on an adhesive bonded clad Al lap joint loaded in shear and irradiated at 25 Cal/sq cm-sec. Rupture times of 1 to 10 sec were obtained for static loads of 30 to 70% of ultimate room temperature strength.

49. EFFECTS OF NEUTRON AND GAMMA-RAY IRRADIATION ON THE DIELECTRIC CONSTANT AND LOSS TANGENT OF SOME PLASTIC MATERIALS. R. A. Weeks and D. Binder. (AIEE Summer General Meeting, June 1958, Paper CP 58-878) also (AIEE Transactions, Winter General Meeting, February 1959)

50. EFFECTS OF GAMMA RADIATION ON SOME ELECTRICAL PROPERTIES OF TEFLON W. E. Loy, Jr. (ASTM, Third Pacific Area National Meeting, San Francisco, California, 11-16 October 1959, Paper No. 193)

Post-irradiation measurements of dielectric constant of 32- and 125-mil Teflon specimens, irradiated to a dose of $5.7 \times 10^7$r, indicated no change from the pre-irradiation values. Dielectric strengths of 3-, 5-, and 11-mil specimens, irradiated to a dose of $5.7 \times 10^7$r, did not change significantly from the pre-irradiation values.

Volume resistivity of Teflon irradiated at dose rates ranging from $3 \times 10^2$ r/hr to $1.85 \times 10^5$ r/hr decreased very rapidly during irradiation. Results indicate that the resistivity during irradiation is an inverse function of dose rate and specimen thickness.

Post-irradiation values of resistivity indicate a dependence on the dose.

51. RADIATION EFFECTS IN POLYSTYRENE. Donald E. Kline. (Applied Polymer Science, Journal, Vol. 5, No. 14, March-April 1961, pp. 191-194)

Amorphous polystyrene was subjected to nuclear radiation in doses ranging from $1.2 \times 10^{10}$ to $3.8 \times 10^{11}$ ergs per gram. At low irradiation doses cross-linking occurred sufficient for the formation of a non-liquefying, three-dimensional network in the polystyrene, but no changes in the dynamic mechanical properties attributable to irradiation could be detected.

52. ULTRAVIOLET RADIATION DEGRADATION OF ELASTOMERS IN A HIGH VACUUM. C. D. Miller. (Armour Research Foundation, Chicago, Illinois, Contract AF 33(616)-7310, Report on Nonmetallic and Composite Materials, May 1960-May 1961, September 1961, 19 p., 30 refs., ASD TR 61-84) AD-268 994

A test chamber was designed and constructed for the irradiation of suitable elastomers at short wavelengths (greater than 2000 A), low pressures (less than 10 to the -5th power mm Hg), ambient temperatures (less than 300 F), and low relative elongation (less than 25%). Quantities measured include stress decay, weight loss, and changes in elastic modulus; these are all bulk properties and show no apparent change at temperatures less than 225 F. However, there was appreciable surface deterioration, as evidenced by dulling, cracking, permanent set, and unequal swelling. At higher temperatures (300 F) the bulk properties show significant changes, indicating a homogeneous thermal reaction throughout the specimen, superimposed on the surface photolysis. The samples differ notably in durability; the Viton fluoroelastomers seem to resist degradation most successfully.

53. EFFECTS OF IONIZING RADIATION ON NATURAL AND SYNTHETIC HIGH POLYMERS. Frank A. Bovey, Minnesota Mining and Manufacturing Company, St. Paul, Minnesota. (Interscience Publishers, Inc., New York, 1958, 287 p., Refs. by Chapters)

Contents: Properties of ionizing radiations; Chemical Effects producted by ionizing radiations; Radiation chemistry of polymers (general); Statistical treatment of crosslinking and scission occurring under ionizing radiation; Hydrocarbon polymers; Acrylate and methacrylate polymers and miscellaneous oxygen-containing addition polymers; Chloro and fluoro polymers; Diolefin polymers; Condensation polymers; Natural polymers and derivatives; Appendix - Effects of high energy radiation on polymers.

54. EFFECT OF NUCLEAR RADIATION ON METALLO-ORGANIC COMPOUNDS AND ON POLYETHYLENE. N. J. Broadway. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Contract AF 33(616)-5171, Technical Memorandum No. 3, 15 February 1958, 5 p., 11 refs.)

55. EFFECT OF NUCLEAR RADIATION ON ELASTOMERIC AND PLASTIC MATERIALS. N. J. Broadway, M. A. Youtz, M. L. Zaring and S. Palinchak. (Battelle Memorial Institute, Radiation Effects Information Center, REIC Report No. 3, 31 May 1958, 160 p., 37 refs.) AD-149 552

This report presents the state of the art of the effects of nuclear radiation on elastomeric and plastic materials from 1947 to the present. A brief description of the mechanism of radiation damage is followed by detailed presentation of data summarizing the radiation-effects information on various types of elastomers and plastics. Also, areas in which more research is needed are indicated. This report does not include information on the use of radiation for polymerization or vulcanization unless it has some bearing on effects of radiation on the finished polymer.

The information in this report is not new, but it is believed that it is sufficiently inclusive and is presented in a form which will make it valuable as a reference guide to the engineers designing nuclear weapon systems.

56. EFFECT OF NUCLEAR RADIATION ON FLUOROPOLYMERS. N. J. Broadway and S. Palinchak. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Memorandum 17, 30 June 1959, 18 p., 27 refs.)

This memorandum summarizes the available data on the radiation stability of Teflon and Kel-F plastics, and Kel-F, polyfluorobutyl, acrylate (PolyFBA) hexafluoropentamethylene adipate (a polyester), and Silastic LS-53 (a fluorinated silicone) elastomers.

57. EFFECT OF NUCLEAR RADIATION ON ELASTOMERIC AND PLASTIC COMPONENTS AND MATERIALS. R. W. King, N. J. Broadway and S. Palinchak. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Contract AF 33(616)-7375. REIC Report No. 21, 1 September 1961, 344 p., 205 refs.) AD 267 890

This report presents the state of the art of the effects of nuclear radiation on elastomeric and plastic components and materials from 1947 to the present.

The mechanism of radiation damage and the effects of radiation in various environments are briefly discussed. Data summarizing the radiation-effects information on specific components and on the various types of elastomers and plastics are presented in detail. Areas in which additional work is needed are indicated. Radiation polymerization or vulcanization are included only if the data have a bearing on radiation effects on the finished polymer.

This report is intended to be sufficiently inclusive to make it valuable as a reference guide on the effects which can be anticipated from nuclear radiation on elastomeric and plastic components and materials.

58. EFFECTS OF HIGH VACUUM AND ULTRAVIOLET RADIATION ON PLASTIC MATERIALS. Norman E. Wahl and Roy R. Lapp. (Cornell Aeronautical Laboratory, Inc., Buffalo, New York, Contract AF 33(616)-6267, Report on Non-Metallic and Composite Materials, July 1960, 63 p., 10 refs., WADD TR 60-125) AD-245 211L*

*NO AUTOMATIC RELEASE TO FOREIGN NATIONALS.

This study was concerned with the behavior of plastic materials exposed to simulated conditions of pressure, temperature and near ultraviolet as encountered outside the earth's atmosphere. Glass fiber reinforced plastic laminates, of three types, were exposed to vacua in the order of $10^{-6}$ $10^{-7}$ mm Hg and ultraviolet flux ranging from 1/3 to 2-1/2 times the solar constant of 2 calories $cm^{-2}$ $min^{-1}$. The periods of exposure ranged from 3 to 500 hours. The equilibrium temperatures of the laminates varied from 250° to 465°F depending on the intensity of the ultraviolet employed. After exposure to ultraviolet radiation equivalent to the solar constant and vacuum, for periods up to 500 hours, no great change in dimensions or loss in weight of the laminates was observed. The strength of the polyester specimens, however, tends to increase while the phenolic and epoxy laminates decrease slightly in strength. Laminates exposed to ultraviolet flux of 4.9 calories $cm^{-2}$ $min^{-1}$ and vacuum for three hours show considerable loss in weight and flexural strength.

59. STUDY OF THE EFFECTS OF NUCLEAR RADIATIONS ON ELASTOMERIC COMPOUNDS AND COMPOUNDING MATERIALS. D. J. Harmon. (B. F. Goodrich Company, Research Center, Brecksville, Ohio, Contract AF 33(616)-5646, Quarterly Progress Report No. 3, 15 January 1959) AD 229 865

60. EFFECTS OF GAMMA RADIATION ON THE DIELECTRIC PROPERTIES OF SOME ELECTRIC INSULATING MATERIALS. 2. PHENOL-FORMALDEHYDE PLASTICS. K. A. Vodop'ianov, B. I. Vorozhtsov and G. I. Potakhova. (Izvest. Vysshikh Ucheb. Zavedenii, Fizika, No. 3, 1960)

61. EFFECT OF VACUUM AND ULTRAVIOLET RADIATION ON POLYMERIC MATERIALS. AN ANNOTATED BIBLIOGRAPHY. Helen M. Abbott. (Lockheed Aircraft Corporation, Sunnyvale, California, Special bibliography No. SB-61-20, April 1961, 26 p., 60 refs.) AD-256 192

An annotated bibliography is presented consisting of 60 selected references on polymeric materials that have been investigated under the space conditions of vacuum and ultraviolet radiation. The references are arranged alphabetically by author. The following sources were used: ASTIA, LNSD card catalog. Aeronautical Engineering Index: 1957-1955, Resins, Rubber and Plastics: 1960-1955. Nuclear Science Abstracts: 1959-1951. Engineering Index: 1960-1953. Science Abstracts: 1959-1958. Modern Plastics, and Plastics Technology.

62. RADIATION EFFECTS ON TEFLON: AN ANNOTATED BIBLIOGRAPHY. William L. Hollister. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 04(647)-840, Report No. 3-88-61-2, Special Bibliography No. SB-61-65, February 1962, 41 p.) AD-273 135

63. EFFECT OF RADIATION ON PLASTIC FILMS. Charles F. Bersch, Robert R. Stromberg, and Bernard G. Achhammer. (Modern Packaging, Volume 32, No. 12, August 1959, pp. 117-121+)

Low- and high-density polyethylenes, polyethylene terephthalate, polystyrene, Pliofilm, polyvinylidene chloride, and polymonochlorotrifluoroethylene chloride films were exposed to 5.6 and 0.93 megarads in order to study the relation between their chemical structure and radiation stability.

64. ELECTRON IRRADIATION OF POLYTHENE. A. C. Baskett and C. W. Miller. (Nature, Vol. 174, 1954, pp. 364-365)

65. DEGRADATION OF POLYMERS BY ULTRAVIOLET IRRADIATION. PART I. WHEN SUBJECTED TO RADIATION OF THE "NEAR" ULTRAVIOLET REGION IN AIR. A. L. Alexander and F. M. Noonan. (Naval Research Laboratory, Washington, D. C., NRL Report 5257, February 1959, 11 p.) AD 212 987 (see also) AD 149 552

One phase of a research program to develop suitable coatings for space vehicles is concerned with studying the effects of ultraviolet radiation of typical polymeric coatings in air. These coatings may be used to control the absorption and emission of radiant energy by the underlying bodies, and to be effective the coatings must be physically and chemically stable to the high-altitude environments in which they should serve. The initial study under this general program required irradiating a number of typical polymeric coatings with a near-ultraviolet source at ambient conditions for about 300 hours. Infrared absorption data were collected on the film samples before, during, and after this exposure to determine the degradation brought about by the radiation. It was observed that the relative stability to the polymeric materials which were irradiated roughly parallels their relative order of stability to gamma radiation.

66. NUCLEAR RADIATION EFFECTS ON ELASTOMERS. (North American Aviation, Inc., Space and Information Systems Division, Downey, California, Report SID-62-386, April 1962)

67. RADIATION STABILITY OF PLASTICS AND ELASTOMERS. C. D. Bopp and and O. Sisman. (Nucleonics, Vol. 13, No. 7, July 1955, pp. 28-33)

68. EFFECTS OF IONIZING RADIATION UPON TRANSPARENT MATERIALS. Gregory Arutunian and Fred L. Seppi. (Ordnance Tank-Automotive Command, Detroit Arsenal, Center Line, Michigan, RR-1, October 1959)

69. EFFECTS OF RADIATION ON PLASTICS. PART I--POLYSTYRENE AND RELATED MATERIALS. Arthur Bradley, Radiation Corporation, Westbury, Long Island, New York. (Plastics Design and Processing, Vol. 1, No. 6, November 1961, pp. 18-24, 20 refs.)

This article describes work being done by Radiation Research Corporation is studying the effects of radiation on the properties of polystyrene and materials related to polystyrene.

70. EFFECTS OF RADIATION ON PLASTICS. PART II--POLYETHYLENE, TFE-FLUOROCARBON, POLYESTER FILM. Arthur Bradley, Radiation Research Corporation, Westbury, Long Island, New York. (Plastics Design and Processing, Vol. 1, No. 7, December 1961, pp. 24-29, 20 refs.)

This article describes work being done by Radiation Research Corporation in studying the effects of radiation on the properties of polyethylene, TFE-fluorocarbon, polyester film and a "radiation resistant plastic" developed by Bendix Corporation.

71. EFFECTS OF NUCLEAR RADIATION ON STRUCTURAL PLASTICS. R. L. Keller. (Society of the Plastics Industry, Inc., Reinforced Plastics Division, 14th Annual Technical and Management Conference, Chicago, Illinois, 3-5 February 1959)

72. ELECTRICAL PROPERTIES OF IRRADIATED POLYMERS. Ralph E. Woodard. (U. S. Air Force, WADC Technical Report 56-465, June 1957) AD-130 801

73. EFFECTS OF HIGH VACUUM AND ULTRAVIOLET RADIATION OF PLASTIC MATERIALS. Norman E. Wahl and Roy R. Lapp, Cornell Aeronautical Laboratory (U. S. Air Force, Wright Air Development Division, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, Project No. 7340, WADD Technical Report 60-125, February 1960, 63 p., 10 refs.)

This study was concerned with the behavior of plastic materials exposed to simulated conditions of pressure, temperature and near ultraviolet as encountered outside the earth's atmosphere.

74. GAMMA IRRADIATION OF FLUOROCARBON POLYMERS AND SMALL MOLECULES. L.A. Wall and R.E. Florin. (United States Air Force, Office of Aerospace Research, Aerospace Research Laboratory, ARL 62-350, May 1962, 11 p.)

Summary of work upon the effects of gamma irradiation on fluorocarbon polymers and small molecules, including a list of publications. The subject matter includes physical properties (principally zero-strength-times and tensile strengths); volatile products; effects of oxygen and chlorine atmospheres; radiation chemistry of perfluoroheptane, hexafluorobenzene and mixtures: sensitizing of radiation-induced polymerization; and yields of radicals by electron spin resonance.

75. MOLECULAR CHANGES IN POLYAMIDE AND ELASTOMERIC POLYMERS DUE TO NUCLEAR, ULTRAVIOLET AND THERMAL RADIATION. G. Hargreaves. (U. S. Navy, Naval Air Material Center, Aeronautical Materials Laboratory, Philadelphia, Pennsylvania, Progress Report No. 4, 16 June-15 December 1961, 15 December 1961, 5 p., 8 refs.) AD-272 964L*

*ALL REQUESTS REQUIRE APPROVAL OF Bureau of Naval Weapons, Navy Department, Washington 25, D. C.

SECTION A

## Radiation Effects

### 5. Semiconductors

76. EFFECTS OF NUCLEAR RADIATION ON SEMICONDUCTOR DEVICES. M. Bertolotti. (Alta Frequenza, Vol. 30, No. 9, September 1961, pp. 631-642; No. 12, December 1961, pp. 862-872, 120+ refs.)

The types of damage are classified and the effects of various forms of radiation are reviewed.

77. EFFECT OF NUCLEAR RADIATION ON SEMICONDUCTOR MATERIALS. F. J. Reid, J. W. Moody and R. K. Willardson. (Battelle Memorial Institute, Radiation Effects Information Center, Report No. 1, 20 December 1957, 48 p.) (LC mi$3.30, ph$7.80) PB-147 101

A literature survey is presented on radiation effects in semiconductor materials. Results indicate that Ge is relatively radiation resistant. From 1 to 30 ohm-cm Ge the minority-carrier lifetime and the conductivity begin to be affected at about 10 fastneutrons/sq cm. Less pure Ge ($<$ 1 ohm-cm) gives greater radiation resistance. Si appears to be less radiation resistant than Ge by as much as a factor of 2.

78. EFFECT OF NUCLEAR RADIATION ON SEMICONDUCTOR DEVICES. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Report No. 10, 30 April 1960) AD-240 433

79. EFFECT OF NUCLEAR RADIATION ON SEMICONDUCTOR DEVICES. FIRST ADDENDUM. F. J. Reid. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC No. 10, Addendum No. 1, 15 July 1961, 36 p.) AD-262 081

80. EFFECTS OF CONTINUOUS GAMMA RAY OR PULSED NEUTRON RADIATION ON SEMICONDUCTOR DIODES. Howard L. Steele. (Boeing Airplane Company, Seattle, Washington, D2-2123, 1959, 36 p.) AD 245 137

The results of ten different diode types exposed to continuous gamma radiation and pulsed neutron plus gamma radiation is presented.

81. RADIATION EFFECTS DATA SHEETS ON TUBES, RESISTORS, CAPACITORS, AND SEMICONDUCTORS. (Electrical Manufacturing, Vol. 63, No. 2, February 1959, pp. 112-117)

82. BEHAVIOR OF SEMICONDUCTOR AND MAGNETIC MATERIALS IN RADIATION ENVIRONMENT. A. Boltax. (Electrical Manufacturing, Vol 63, No. 3, March 1959, p. 92)

83. RESEARCH IN RADIATION DAMAGE IN SEMICONDUCTORS. J. W. Harrity, H. Horlye and others. (General Dynamics Corporation, General Atomic Division, San Diego, California, Contract AF 19(604)-3899, Report No. GA-1201, Final Report, 15 May 1958-15 December 1959, 10 February 1960, 1 Vol., AFCRC TR 60-117) AD-235 017

An experimental program was initiated to study the effect of irradiation on semiconducting materials and to apply this knowledge to fabricate a radiation-resistant diode. High-energy 25-mev electron bombardment done with the linear accelerator and neutron bombardment done with the TRIGA reactor were used to study the electrical properties of germanium and silicon as a function of total irradiation between 78° and 300°K. The electrical properties studied were the conductivity, Hall effect, and carrier lifetime. The carrier removal rate was found to be 4.0 electrons per centimeter of 25-mev electron path in germanium at 78°K, compared with 0.18 in silicon at 300°K. Two hole-trapping levels were found in germanium with energies above the valence band of 0.15 and 0.27 ev. Evidence of annealing was also observed between 78°K and room temperature in germanium. The result of these studies was the fabrication of a radiation-resistant diode using p-type germanium with a resistivity of about 0.20 ohm-cm as the base material.

84. SEMICONDUCTOR DIODE PERFORMANCE IN NUCLEAR RADIATION ENVIRONMENTS. H. G. Homre and M. E. Goldberg. (Illinois Institute of Technology, Armour Research Foundation, Chicago, Illinois, ARF-5134-8, Interim Scientific Report No. 1, 15 November 1960)

85. RADIATION EFFECTS IN SEMICONDUCTORS: THERMAL CONDUCTIVITY AND THERMOELECTRIC POWER. T. H. Geballe. (Journal of Applied Physics, Vol. 30, August 1959, pp. 1153-1157)

86. NATURE OF BOMBARDMENT DAMAGE AND ENERGY LEVELS IN SEMICONDUCTORS. J. H. Crawford, Jr. and J. W. Cleland. (Journal of Applied Physics, Vol. 30, August 1959, pp. 1204-1213)

The different effects of $Co^{60}$ gamma-ray and fast neutron bombardment on the electrical behavior of Ge are discussed in terms of different local distributions of lattice defects expected for these two types of radiation.

87. SEMICONDUCTORS IN A HYPERNUCLEAR ENVIRONMENT. Leonard B. Gardner and Alvin B. Kaufman. (Litton Systems, Inc., Woodland Hills, California, Contract AF 33(600)-41452, August 1961, 45 p., 17 refs., ASD TN 61-100) AD-267 324

Operating characteristics of different types of transistors and diodes were examed during their exposure to a hypernuclear environment. They were selected on the basis of high alpha cutoff frequency, small base width, and low resistivity, and included both silicon and germanium NPN and PNP types. This total integrated exposure was accumulated during 100 hours in the GTR (Ground Test Reactor) facility. The purpose was to find semiconductor devices suitable for application within a servo-amplifier used as part of Litton's NGL inertial guidance platform. Characteristics which were of interest were the dc and ac beta at 400 c and the low collector currents as a function of exposure to the nuclear environment. All semiconductors tested and their observed characteristics before, during, and after irradiation are discussed.

88. RADIATION EFFECTS IN SEMICONDUCTORS. Gunther Wertheim. Bell Telephone Laboratory, Murray Hill, New Jersey. (Nucleonics. Vol. 20, No. 7, July 1962, pp. 47-50, 10 refs.)

Irradiation affects resistivity and reduces carrier lifetime: it causes ionization, which consumes most of the energy but leaves no permanent damage, and displacements, which are the source of permanent damage in semiconductors.

89. RADIATION EFFECTS IN SEMICONDUCTOR DEVICES. James W. Easley, Sandia Corporation, Albuquerque, New Mexico. (Nucleonics, Vol. 20. No. 7, July 1962, pp. 51-56, 28 refs.)

Device behavior is influenced by transient ionization effects and more permanent changes that come from both the radiation production of lattice imperfections and the alteration of surface properties.

90. RADIATION EFFECTS IN COMPOUND SEMICONDUCTORS. L. W. Aukerman. (Proceedings of the Second Conference on Nuclear Radiation Effects on Semiconductor Devices, Materials and Circuits, 1960, pp. 26-30)

The number of carriers removed per incident neutron are compared for the following materials: SiC, Si, GaAs, InP, Ge, AlSb, GaSb, and CdTe. Analysis of post-irradiation measurements indicated bombardment-produced levels in AlSb at 0.33 ev above the valence band, in InP at 0.28 ev below the conduction band, and in GaAs at about 0.14 ev below the conduction band. Below room temperature ($\cong$ 250 K) at "mobility catastrophy" was observed in an irradiated GaAs specimen. High temperature annealing studies carried on GaAs indicate an annealing process at about 300 C, and further annealing above 400 C.

91. SEMICONDUCTORS AND SPACE RADIATION. Leonard B. Gardner, Litton Systems, Inc., Radiation Effects Group, Computer Research Section, Woodland Hills, California. (Solid State Design, Vol. 3, April 1962, pp. 42-46, 12 refs.)

The mechanisms of radiation damage in semiconductors are summarized. The space radiation environment is defined. Some of the difficulties of ascertaining the severity of the space radiation are presented.

A criterion for the selection of semiconductors for application in a space radiation environment is presented. No attempt is made to correlate the observed damage in a neutron environment with that of a proton environment. Included with the selection criteria is a table of several recently developed semiconductors, listed according to their resistance to space radiation.

92. DAMAGE TO SEMICONDUCTORS FROM SPACE RADIATION. W. L. Brown. (Space-Nuclear Conference, Sponsored by American Rocket Society and Oak Ridge National Laboratory, Gatlinburg, Tennessee, 3-5 May 1961, Preprint 1755-61, 22 p.)

93. CHARGED PARTICLE RADIATION DAMAGE IN SEMI-CONDUCTORS, I: EXPERIMENTAL PROTON IRRADIATION OF SOLAR CELLS. J. M. Denney and R. G. Downing. (Space Technology Laboratories, Inc., Los Angeles, California, 8987-0001-RU-000, NAS 5-613, 15 September 1961)

The effect of proton bombardment on solar cells, particularly silicon, has been measured experimentally at proton energies from 20.5 Mev to 740 Mev. Comparison of cell type, cell geometry, and parent material, as well as current-voltage characteristics, spectral response, and current decay, with integrated flux at four proton energies is presented. The control of radiation resistance by oxygen and other factors is discussed, and the observation of annealing in n on p cells at room temperature is noted. Curves summarizing radiation damage rates for power supply design are presented.

94. THEORETICAL AND EXPERIMENTAL STUDIES CONCERNING RADIATION DAMAGE IN SELECTED COMPOUND SEMICONDUCTORS. L. W. Aukerman, E. M. Baroody and R. D. Graft. (U. S. Air Force, Wright Development Division, 15 May 1961, 16 p.) AD-256 340

Anomalously low mobilities produced in n-type GaAs as a result of fast-neutron irradiation are interpreted in terms of inhomogenities in the carrier concentration. The very steep temperature dependence of mobility is still a puzzling feature of these irradiations. Annealing of electron-irradiated n-type GaAs can be analyzed in terms of two first-order processes.

SECTION A

## Radiation Effects

### 6. Solar Cells

95. PERFORMANCE OF SILICON SOLAR CELLS AT HIGH LEVELS OF SOLAR RADIATION. C. Pfeiffer, P. Schoffer, B. G. Spars and J. A. Duffie. (ASME Transactions, Series A, Journal of Engineering for Power, Vol. 84, No. 1, January 1962, pp. 33-38)

Current-voltage characteristics of silicon solar cells cooled by conduction or convection at radiation levels up to 60 langleys per minute are noted, as well as the use of cells as flux measuring devices.

96. NEW RADIATION-RESISTANT HIGH EFFICIENCY SOLAR CELL. B. Mandelkorn and others. (Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey, Technical Report 2153, October 1960) AD-247 184

97. PROTON AND ELECTRON DAMAGE TO SOLAR CELLS. L. W. Aukerman. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Report No. 23, 1 April 1962, 30 p., 82 refs.) AD 274 954

The results of experiments carried out at a number of laboratories to determine the effects of proton and electron irradiation on the performance of solar cells are summarized. Most of the studies were concerned with silicon cells which utilize a p-n junction close to the surface; although, some preliminary results for GaAs solar cells are also included. The results of many laboratories are compared in a $\phi_c$ vs $E_p$ plot, where $\phi_c$ is the integrated proton flux required to reduce the efficiency of the silicon solar cell by 25 per cent under conditions of approximately 100 mw/cm$^2$ artificial illumination, and $E_p$ is the proton energy. The trend suggests that the expected proportionality between $\phi_c$ and $E_p$ holds for energies up to about 200 Mev or higher. The effects of radiation damage on the spectral response are also discussed and the experiments interpreted in terms of radiation-damage theory, where possible.

98. ELECTRONIC IRRADIATION OF SILICON SOLAR CELLS. J. C. Fraser. (General Electric Company, General Engineering Laboratory, Schnectady, New York, Report 60GL143, August 1960)

99. ESTIMATE OF SPACE-RADIATION EFFECTS ON SATELLITE SOLAR-CELL POWER SUPPLIES. J. M. Denney, R. G. Downing, S. R. Lackman and J. W. Oliver, Space Technology Laboratories, Inc., Los Angeles. (IRE Transactions on Military Electronics, Vol. MIL-6, No. 1, January 1962, pp. 14-20, 8 refs.)

The charged-particle intensity and energy distribution at the heart of the inner and outer Van Allen belts is compared with the experimentally determined radiation sensitivity of silicon solar cells. Energy dependence of the radiation damage and solar-cell characteristics is included in the lifetime estimate of spacecraft solar cells. Use of charged-particle range-energy relations and the differential intensity of the Van Allen radiation results in an estimated effectiveness of thin protective shields. Comparative advantages of thin shields, advanced cell designs, solar efficiency, and solar-cell system over-design are discussed with respect to radiation resistance of spacecraft power supplies.

100. RADIATION EFFECTS IN SILICON SOLAR CELLS. F. A. Junga and G. M. Enslow. (IRE Transactions on Nuclear Science, Vol. NS-6, No. 2, June 1959, pp. 49-53)

Estimate of the number of atoms displaced from normal sites by Compton electrons from $Co^{60}$ gamma rays and by slow and fast neutrons. Changes in carrier lifetimes and mobilities are used to predict the performance of a Si solar cell under gamma and neutron irradiation. Effect of annealing is considered.

101. PROTON DAMAGE TO SOLAR CELLS. K. T. Cham and E. A. Lodi. (Lockheed Aircraft Corporation, Missile and Space Division, Sunnyvale, California, Report LMSD-703735, July 1960)

102. PROTON DAMAGE TO SOLAR CELLS. K. T. Chow and E. A. Lodi. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 04(647)-564, Report No. LMSD-703735-1, Technical Report, August 1961, 31 p.) AD-265 213

The performance was evaluated of commercially available silicon solar cells which are to be used as a power source in the space radiation field surrounding the earth. The experiment was specifically designed to provide information on the proton radiation encountered by solar cells operating in space. The results indicated that a 25% reduction in maximum power output of the cell occurred at integrated fluxes of approximately 5 x 10 to the 9th and 10th power protons/sq cm for 3-Mev and 13-Mev protons, respectively. The cells were further irradiated to obtain a reduction in maximum power output of about 40 to 50%. Room-temperature annealing of the cells was observed for a period of four weeks with no significant changes occurring. The proton source, the apparatus for measuring the electrical output of the solar cell, and the results of the experiment are presented.

## SECTION A

## Radiation Effects

### 7. General

103. EVALUATION-DEVELOPMENT OF MIL-C-14157B CAPACITORS FOR NUCLEAR RADIATION ENVIRONMENTS. (Admiral Corporation, Chicago, Illinois, Contract NObsr-77612, Final Development Report, 21 August 1961, 123 p.) D-265 046

The performance is presented of the type CPM08 paper or paper/plastic dielectric capacitor in a combined nuclear-temperature-voltage environment. The principal causes of failure discovered as a result of the environmental test of the standard CPM08 capacity were: gas evolution and a volume resistivity decrease of the dielectric fluid, embrittlement of the paper and hydrolytic degradation of the Mylar. E-200 capacitors performed exceptionally well in the environmental test with insignificant change in capacitance and dissipation factor. This was also the case for Samica dielectric film capacitors impregnant exhibited the best survival rate; however, changes in capacitance, dissipation factor and insulation resistance in the irradiated group were excessive. Isocyanate treated Mylar units failed very rapidly. It appears that the Mylar was not properly prepared to take advantage of the improved properties of the isocyanate treatment of Mylar.

104. EFFECTS OF NUCLEAR RADIATION ON QUARTZ CRYSTAL UNITS. Arthur Donovan, Albert Fueyo and Arnold Schlueter. (Admiral Corporation, Chicago, Illinois, Contract DA 36-039-sc-85322, Report/No. 1, 23 May 1960-22 August 1961, 30 September 1961, 1 Vol.) AD-268 409*

*No automatic release to Foreign Nationals.

The effects of pulsed neutron radiation on the operating characteristics of quartz crystal units were studied. A system was set up for accurately measuring the transient frequency changes occurring in quartz crystals exposed to short-duration (5 micro-seconds) high-density radiation fields. A 20-microseconds portion of the crystal impedance meter output before, during, and after irradiation was photographed from the scope presentation. A fast neutron dose rate equivalent to 10 to the 15th power NV was obtained by bombarding a uranium target for 5 microseconds with a 14 mev electrons from a linear accelerator. The 90 crystal samples tested were mainly AT types ranging from 4 to 85 mc and 2 NT cuts at 50 and 300 kc, including natural and synthetic blanks and both metal- and glass-enclosed types. Tables of frequency measurements and graphical presentations of data for all types tested are included.

105. WHAT RADIATION DOES TO ELECTRONIC COMPONENTS. S. P. Kaprielyon. (Aircraft and Missiles, January 1960, pp. 18-21)

106. EFFECTS OF NUCLEAR RADIATION ON THE ELECTRICAL STRENGTH OF AIR. G. I. Duncan, General Electric Company, Ft. Wayne, Indiana and J. C. Fraser and B. Valachovic, General Electric Company, Schenectady, New York. (AIEE Transactions, Part I, Communications and Electronics, Vol. 79, March 1960, pp. 19-26, 1 ref.)

With the emphasis today upon extended environmental conditions for electronic equipment used in military aircraft and guided missiles, there is a pressing need for the simultaneous testing of such equipment under two or more of these extreme environments. This paper describes a program completed by the General Electric Company covering the testing of spark gaps in the Brookhaven National Laboratory's graphic reactor. It consisted of a 2-week in-pile exposure designed to investigate the voltage breakdown strength of air at various pressures in the presence of intense nuclear radiation.

107. RADIATION-TOLERANT ELECTRONICS. R. M. Magee and D. A. Renken. (AIEE 1960 Pacific General Meeting, 10 August 1960, Paper No. 60-1118)

108. COMPARISON OF TRANSIENT EFFECTS IN ELECTRONICS OBTAINED WITH DIFFERENT NUCLEAR PULSES. P. R. Arendt. (American Nuclear Society Transactions, Vol. 4, No. 1, June 1961, pp. 27-28)

109. RADIATION DAMAGE TO UNIPOLAR TRANSISTORS. R. V. Babcock. (American Nuclear Society Transactions, Vol. 4, No. 1, June 1961, pp. 60-61)

110. STRUCTURAL DAMAGE AND OTHER EFFECTS OF SOLAR PLASMAS. L. Reiffel, Armour Research Foundation, Chicago, Illinois. (ARS Journal, Vol. 30, No. 3, March 1960, pp. 258-262, 29 refs.)

For orbits or trajectories that carry large area lightweight structures outside of protected regions of space defined by planetary magnetic fields, the damaging effects of solar plasma streams are shown to be potentially serious and may result in low durability or high payload penalties. Estimates given depend directly on plasma stream densities and velocities which are only very approximately known. However a reduction by one order of magnitude or more in widely held current estimates of the properties of the solar plasma would still imply a considerable effect on particular structural materials. Substances used as thin coatings on more massive structures would be similarly affected.

111. EFFECTS OF SOLAR RADIATION PRESSURE UPON SATELLITE ATTITUDE CONTROL. R. J. McElvain. (ARS Guidance, Control and Navigation Conference, Stanford, California, 7-9 August 1961, Preprint 1918-61, 26 p.)

Study of the effects of torques due to solar radiation pressure acting on satellite vehicles. Expressions are developed for two cases of practical interest; spin-stabilized vehicles, and vehicles with solar arrays and active attitude control systems which orient the vehicle in an Earth-Sun reference. The results indicate that the solar pressure may cause torques that are either periodic or constant with respect to inertial space, depending on the orbital inclination to the ecliptic plane, the orientation requirements, and the vehicle configuration. The approximate solutions can be used to determine the vehicle angular momentum storage and/or removal requirements resulting from solar radiation torques.

112. NUCLEAR RADIATION AND ELECTRONIC EQUIPMENT. J. R. Crittenden. (Applications and Industry, No. 46, January 1960, pp. 423-426)

Suggestions for designing radiation-tolerant electronic amplifiers are given as follows: Keep resistance values low. Use materials compatible with the environment. Avoid large capacitor values. Keep the circuit simple.

113. EFFECTS OF NUCLEAR RADIATION ON NIKE HERCULES GUIDANCE SYSTEM. William A. Conway and C. D. Hurd. (Army Missile Test Center, White Sands Missile Range, New Mexico, Technical Memo 791, December 1960)

114. TRANSIENT EFFECTS OF PULSE NUCLEAR RADIATION ON ELECTRONIC PARTS AND MATERIALS. A. L. Long and H. J. Deganhart. (Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey, Technical Report 2007, 20 January 1959) AD-227 502

115. EFFECTS OF PULSED NUCLEAR RADIATION ON ELECTRONIC MATERIALS. Erik G. Linden and Alton L. Long. (Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey, ASRDL TR 2030, 1 October 1959, 38 p.) AD- 235 666L*

*Notice: Only Military Offices may request from Astia. All others request approval of U.S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey.

A static study was conducted on various materials of the effects on electrical properties of pulses of nuclear radiation from the Godiva reactor.

116. PRELIMINARY OBSERVATIONS ON A PARTICULAR EFFECT OF NUCLEAR RADIATIONS ON ELECTRODE PROCESSES. L. Busulini. (Associated Technical Services Incorporated, East Orange, New Jersey, ATS-73N541, 1961, 2 p.)

117. RADIATION EFFECTS ON COMPUTER CIRCUITRY. Albert Lucic. (Autonetics, A Division of North American Aviation, Inc., Anaheim, California, Report TM-3341-10-5, 7 November 1961, 50 p., 22 refs.)

118. EFFECT OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS AND SYSTEMS. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Report No. 2)

119. EFFECT OF NUCLEAR RADIATION ON CERAMIC MATERIALS. W. C. Riley, W. G. Coppins, W. A. Hedden and W. H. Duckworth. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Report No. 2-C, 30 June 1958, 82 p., 535 refs., SECRET) AD-157 173

This report presents the state of the art on the effects of nuclear radiation on ceramic materials through 1957.
The various ceramic materials likely to be required in a nuclear-powered vehicle are described, and the available information concerning the effects of nuclear radiation on these materials is analyzed.

120. EFFECT OF NUCLEAR RADIATION ON ELECTRICAL AND ELECTRONIC SYSTEMS. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Report No. 4-C, 15 March 1960, SECRET RESTRICTED)

121. EFFECT OF NUCLEAR RADIATION ON STRUCTURAL METALS. B. C. Allen, A. K. Wolff and others. (Battelle Memorial Institute, Radiation Effects Information Center, REIC Report No. 5, 12 October 1959, 43 p.)

General effects of various types of radiation on metals are discussed and the damage mechanisms are outlined. Describes the effects of fast neutrons on the physical and electrical properties and corrosion resistance of metals. Experimental evidence to date indicates that structural metals are quite resistant to nuclear radiation when compared to such things as organic compounds or electronic components.

122. EFFECT OF NUCLEAR RADIATION ON SEALS, GASKETS, AND SEALANTS. N. J. Broadway and S. Palinchak, (Battelle Memorial Institute, Radiation Effects Information Center, Columbus 1, Ohio, AF 33(616)-5171, Technical Memorandum No. 8, 30 November 1958, 9 p., 16 refs.)

In a nuclear-powered vehicle, sealing materials such as gaskets, O-rings, and sealants must be resistant to radiation in addition to being stable to heat, oils, fuels, and hydraulic fluids. At present, there is no rubber or plastic sealing material available which has high radiation stability. However, several materials may be utilized for limited service in a radiation environment. Some of the more recent fluoroelastomers, such as Viton-A and Elastomer 214, and some of the silicones appear to be among the better high-temperature radiation resistant materials available. However, rubber and plastics such as nitrile rubber, neoprene, and polyethylene may be used under less severe temperature conditions in a radiation environment.

123. EFFECT OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS. D. J. Hamman, W. E. Chapin, J. F. Hansen and E. N. Wyler. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Report No. 12, 30 April 1960, 66 p., 91 refs.) AD 238 311

This report presents information to cover the state of the art of knowledge on the effects of nuclear radiation on basic electronic parts for the past year. It attempts to relate the observed degradation of electrical characteristics of each device to the materials used in the construction of the device. The statements made in the report are not intended to be design oriented, but rather to survey the relative radiation sensitivity of electronic components and to provide a basis for judging the merits of any technical approach for applying electronic circuitry in a radiation environment. The report contains an expanded section on electron tubes and contains information on electronic parts that have not been considered.

124. EFFECT OF NUCLEAR RADIATION ON MAGNETIC MATERIALS. F. J. Reid and J. W. Moody. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Contract AF 33(616)-5171, Technical Memorandum No. 12, 31 December 1958, 14 p., 14 refs.)

Structure sensitive properties of magnetic materials, such as permeability, remanence, and coercive force, are affected by nuclear irradiation. These effects are most serious in the nickel-iron alloys, and irradiations to $10^{17}$ fast n $cm^{-2}$ are sufficient to cause drastic changes in their magnetic properties. The properties of silicon irons, aluminum irons, 2V Permendur and several ferrites are not seriously affected up to $10^{17}$ fast n $cm^{-2}$. Magnetic amplifiers have been operated successfully up to $10^{15}$ fast n $cm^{-2}$ with no damage observed in the core materials.

This memorandum includes a list of current programs that the Radiation Effects Information Center has identified as being related to radiation effects on magnetic materials.

125. EFFECT OF NUCLEAR RADIATION ON PROTECTIVE COATINGS. R. Mayer, N. J. Broadway and S. Palinchak. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Report REIC No. 13, 15 July 1960)

126. EFFECT OF NUCLEAR RADIATION ON ELECTRICAL INSULATING MATERIALS. J. W. Moody. (Battelle Memorial Institute, Radiation Effects Information Center, Memorandum No. 14, 31 March 1959)

127. EFFECT OF NUCLEAR RADIATION OF HOSES AND COUPLINGS. M. C. Schroeder. (Battelle Memorial Institute, Radiation Effects Information Center, REIC Memorandum 15, 31 March 1959, 3 p., 5 refs.)

This report summarizes the results of the relatively few experiments conducted so far on the effects of nuclear radiation on standard aircraft hoses and couplings. It does not include the results of studies on the solid organic materials themselves normally used in hose manufacture.

128. EFFECT OF NUCLEAR RADIATION ON REFRIGERANTS. Robert E. Wyant. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Memorandum 16, 30 June 1959, 6 p., 14 refs.)

This memorandum summarizes the information available at REIC on the radiation stability of the common refrigerants. For most of the refrigerants only a meager amount of information is now available.

129. EFFECT OF NUCLEAR RADIATION ON STRUCTURAL ADHESIVES. N. J. Broadway and S. Palinchak. (Battelle Memorial Institute, Radiation Effects Information Center, REIC Report No. 17, 1 March 1961) AD-256 954

Summarizes the radiation stability of adhesives and suggests the areas in which further work is required. The radiation stabilities of various types of adhesives which have been reported are compared, showing the maximum doses at which they may be expected to give satisfactory service. Tensile-shear data are used primarily for these comparisons because this information has been obtained for the greatest number of adhesives. Bend-test data are also used as a means of comparison where such data are available.

130. EFFECT OF NUCLEAR RADIATION ON ELECTRONIC COMPONENTS. D. J. Hamman, W. E. Chapin, C. L. Hanks and E. N. Wyler. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Contract AF 33(616)-7375, REIC Report No. 18, 1 June 1961, 154 p., 109 refs.)

This report presents information which covers the state of the art of knowledge on the effects of nuclear radiation on basic electronic parts that is available in the REIC files. As such, it represents a summary of information accumulated within the past year plus information previously reported in REIC reports. Some information pertinent to this compilation of radiation effects was also obtained from REIC Technical Memorandums. This report presents component results that are grouped as to family within each component class type. The results presented in the report are intended to provide a basis for judging the merits of the parts when they are to be used in circuitry that will be exposed to a radiation environment. Some of the data included in the report can be considered as design oriented to the extent that they indicate radiation levels at which the parts can be expected to perform satisfactorily.

131. SPACE RADIATION AS AN ENVIRONMENTAL CONSTITUENT. Raymond E. Hess and Robert F. Badertscher. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, REIC Memorandum 19, 15 January 1960, 48 p., 51 refs.)

This Memorandum has been prepared to summarize the radiation data obtained from the satellites and moon probes. The data presented are primarily those of the American program. A reasonable volume of Soviet data has become available, and these have been freely used. In view of the continual input of space data, it must be emphasized that the description presented may be subject to extensive modification in the future.

Any consideration of space radiation may be divided logically into two sections; this natural division is followed here. The first section deals with cosmic rays in interplanetary space; the second section deals with the much-discussed Van Allen radiation belts. The Van Allen belts might be classed as earth-related phenomena, wereas cosmic-ray phenomena in space are independent of the earth.

132. EFFECT OF NUCLEAR RADIATION ON STRUCTURAL METALS. Frederic R. Shober. (Battelle Memorial Institute, Radiation Effects Information Center, Contract AF 33(616)-7375, REIC Report No. 20, 15 September 1961, 101 p., 85 refs.)

The effect of fast neutron ( 1 Mev) irradiation on the mechanical properties of structural metals and alloys is somewhat unique in that some properties show changes which are detrimental while others are enhanced by irradiation. Although the yield strengths and ultimate tensile strengths are increased substantially for most materials, the ductility suffers severe decreases. This report presents these changes in properties of several structural metals for a number of neutron exposures within the $1.0 \times 10^{18}$ to $5.0 \times 10^{21}$ n $cm^{-2}$ range. Data summarizing these effects on several classes of materials such as carbon steels, low-alloy steels, stainless steels, zirconium-base alloys, nickel-base alloys, aluminum-base alloys, and tantalum are given. Additional data which show the influence of irradiation temperatures and of post-irradiation annealing on the radiation-induced property changes are also given and discussed.

The Appendix consists of an annotated bibliography of radiation effects publications on structural metals and alloys.

133. RADIATION EFFECTS STATE OF THE ART 1960-1961. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Contract AF 33(616)-7375, REIC Report No. 22, 30 June 1961, 52 p.) AD-264 050

A series of memoranda is presented summarizing briefly (1) the current state of the art, (2) programs in progress, and (3) Battelle's conclusions and recommendations in the following areas: electronic components and equipment; semiconductor devices and materials; polymeric materials; fluids; lubricants, and hydraulic fluids; structural metals and ceramic materials; space radiation; and dosimetry and units. The report is oriented around steady-state nuclear-radiation effects; however, considerations regarding the less well-defined areas of pulse radiation and space radiation are included.

134. RADIATION DOSIMETRY: AN ANNOTATED BIBLIOGRAPHY. Mary Jane Oestmann. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Contract AF 33(616)-7375, REIC Memo. No. 23, 15 September 1961, 62 p.) AD-265 523

135. ELECTRICAL LEAKAGE IN INSULATORS EXPOSED TO A NUCLEAR ENVIRONMENT. G. E. Lamale and P. Schall. (Battelle Memorial Institute, Radiation Effects Information Center, Columbus, Ohio, Contract AF 33(616)-5171, 15 January 1958, 4 p., 5 refs.)

136. FINAL REPORT ON THE EFFECTS OF GAMMA INDUCED IONIZATION ON THE ELECTRICAL PROPERTIES OF PRINTED CIRCUITS AND CONNECTORS TO CHANCE-VOUGHT AIRCRAFT. J. F. Hansen and H. Cary. (Battelle Memorial Institute, 5 March 1959)

137. NEEP NUCLEAR ELECTRONIC EFFECTS PROGRAM. (Bell Telephone Laboratories, Inc., Whippany, New Jersey, Contract AF 33(600)-32662, 10 Quarterly Report, 15 September-15 December 1958, 31 December 1958) AD 214 533

138. NUCLEAR IRRADIATION OF FANSTEEL EXPERIMENTAL CAPACITORS. (Bendix Aviation Corporation, Systems Division, Ann Arbor, Michigan, Contract AF 33(600)-35026, BSR-95, Test Report, 6 January-24 February 1959, April 1959)

139. DIGEST OF IRRADIATION TOLERANCE OF ELECTRONIC COMPONENTS. D.A. Renken and R.M. Magee. (Bendix Systems Division, Ann Arbor, Michigan, Contract AF 33(600)-35026, BSR-230, May 1960, 747 refs.) AD-256 330

140. RADIATION-TOLERANT ELECTRONIC EQUIPMENT. J. R. Burnett. (Bendix Technology Journal, October 1960, pp. 17-20)

141. RADIATION DAMAGE IN SOLIDS. Douglas S. Billington and James H. Crawford, Jr. (Princeton University Press, New Jersey, 1961, 450 p.)

Covers metals, alloys, covalent crystals, and ionic crystals; investigations of semiconductors; radiation effects in fissionable materials; radiation effects in graphite; theory of radiation damage; and the role of defects in the determination of the physical behavior of solids.

142. GAMMA IRRADIATION OF STAR-TRACKER COMPONENTS. J. A. Barton and H. L. Steele. (Boeing Airplane Company, Seattle, Washington, D2-1662)

143. EFFECTS OF GAMMA RADIATION ON ELASTOMERS, SEALANTS, STRUCTURAL ADHESIVES, LUBRICANTS, AND GREASES. Chester J. DeZeih. (Boeing Airplane Company, Seattle 24, Washington, Issue 33, Document D2-2449, 46 p.)

144. ANALYSIS OF SOLAR-FLARE HAZARD TO MANNED SPACE SYSTEMS. E. L. Chupp and others. (Boeing Company, Report D2-11608)

145. RADIATION AND OTHER ENVIRONMENTAL EFFECTS ON SATELLITES. R. Innes. (British IRE, Journal, Vol. 22, September 1961, pp. 241-250)

146. RADIATION EFFECTS ON ELECTRONIC COMPONENTS. P. S. Miglicco. (Convair, Fort Worth, Texas, FZM-915, 1 May 1957)

147. EFFECTS OF RADIATION ON ELECTRICAL INSULATION. P. M. Johnson. (Convair, Ft. Worth, Texas, Report FZM-1897, 15 August 1960)

148. EFFECTS OF REACTOR RADIATION ON THE ELECTRICAL PROPERTIES OF ELECTRONIC COMPONENTS. PART VII. RESISTORS AND VACUUM TUBES. E. E. Palmer and D. Howell. (Convair, Ft. Worth, Texas, Contract AF 33(600)-38946, Document No. NARF-61-5T, Report No. MR-N-268, 7 June 1961, 74 p.) AD-258 946

Several types of vacuum tubes and resistors were irradiated at Convair-Fort Worth with the Ground Test Reactor for a period of 100 hours at a power level of 1 megawatt. Data were taken on the components before, during, and after the irradiation. The vacuum tubes received a maximum radiation exposure of 8.64 x 10 to the 15th power nf/sq. cm and 3.9 x 10 to the 10th power ergs/gm(C). A small increase in the average plate current was noted for all tube types. Pentodes subjected to the high-flux field exhibited the largest percent change (approx. 6%) while diodes remained relatively unaffected at these radiation levels. The resistors received a maximum radiation exposure of 1.4 x 10 to the 16th power nf/sq. cm and 6.2 x 10 to the 10th power ergs/gm(C). The degree of damage was dependent upon the material and type of construction of the individual resistor types. The maximum observed change (approx. 6%) occurred in the RC41 fixed-composition resistors.

149. AIRBORNE TAPE FOR USE IN NUCLEAR ENVIRONMENTS. J. M. Vallin. (Diamond Ordnance Fuze Laboratories, Washington, D. C. Report TR-919, 20 June 1961)

150. RADIATION EFFECTS IN SOLIDS. G. J. Dienes and G. H. Vineyard, Brookhaven National Laboratory, Department of Physics, New York. (Interscience Publishers, Inc., New York, 1957, 226 p., 53 refs.)

The book is concerned mostly with the physics of radiation effects, not with the chemistry of such effects, and not at all with biological effects. This means that displaced atoms have been given more prominence than ionization, and that organic substances have been given far less space than other types of solids. It should also be noted that we are primarily concerned with energetic radiation, of X-ray energies and higher, and thus effects of optical, infrared and ultraviolet irradiation are omitted. Although these phenomena are unquestionably radiation effects, their study goes much farther back, they have been reviewed in many places, and the theoretical ideas involved are sufficiently different from those relevant to high-energy radiation to allow a practical separation.

151. STUDY OF TERRESTRIAL CORPUSCULAR RADIATION AND COSMIC RAYS DURING THE FLIGHT OF THE COSMIC ROCKET. S. N. Vernov, A. Ye. Chudakov, P. V. Vakulov and Yu. I. Logachev. (Doklady Akademii Nauk, SSSR, Vol. 125, No. 2, 1959, pp. 304-307)

152. NUCLEAR RADIATION AND ELECTRONIC EQUIPMENT. J. R. Crittenden. (Electrical Engineering, Vol. 78, September 1959, pp. 898-901)

Chemical and electrical degradation occurs in electronic equipment under nuclear radiation. Problems and suggested solutions associated with the design and development of radiation-tolerant equipment are discussed.

153. EFFECT OF HIGH INTENSITY RADIATION ON ELECTRONIC PARTS AND MATERIALS. C.P. Lascaro and A.L. Long, United States Army Signal Research and Development Laboratory. Fort Monmouth, New Jersey. (Electrical Manufacturing, Vol. 62, No. 3, September 1958, pp. 119-121+, 4 refs.)

A preliminary study of neutron and gamma radiation effects on components and materials used in Signal Corps equipment. This report gives test results and indications of problems arising from irradiation of equipment in a nuclear blast area of high energy radiation.

154. NUCLEAR RADIATION DAMAGE TO TRANSISTORS. (Electrical Manufacturing, July 1960, pp. 78-85)

155. EFFECTS OF GAMMA-RAY IRRADIATION ON CARBON RESISTORS. T. Nakai and T. Sakakibara. (Electromechanical Journal of Japan, Vol. 6, No. 2, 1961, pp. 43-47)

156. SILICON-CARBIDE RECTIFIERS OPERATE IN HIGH-HEAT AND RADIATION ENVIRONMENTS. (Electronic Design, 2 March 1960, p. 38)

157. RADIATION EFFECTS STILL UNKNOWN. (Electronic Design, Vol. 10, No. 2, 18 January 1962, p. 172)

Little is known about the radiation effects on solar cells and semiconductors. Methods of shielding are briefly discussed and radiation damage experiments to be carried by the TELSTAR and RELAY satellites are described.

158. DESIGNERS TAKE NEW TACK TO COUNTER RADIATION EFFECTS. Joel Strasser. (Electronic Design, Vol. 10, 29 March 1962, pp. 8-11)

Discussion of the effects of environmental and nuclear-power-plant radiation on electronic components in space vehicles. The behavior of vacuum tubes and semiconductors during and after exposure to radiation is reviewed, and typical failure points for damage due to atom displacement are tabulated for a variety of components. Shielding techniques, for protection of both entire systems and of individual components, are outlined, as are techniques based on the use of radiation-tolerant materials and special circuit designs.

159. HOW RADIATION EFFECTS ELECTRONIC EQUIPMENT. T.R. Nisbet. (Electronic Equipment Engineering, Vol. 7, No. 5, May 1959, pp. 36-40)

Several types of radiation limit the life expectancy of electronic gear. Equipment can be designed for a given radiation evnironment by closely scrutinizing its function in search of a means of limiting the seriousness of radiation damage. A graphical method of predicting life of equipment is presented that employs plots of flux-dosage.

160. EFFECTS OF NUCLEAR RADIATION ON ELECTRONIC MATERIALS. V. R. Honnold and C. W. Perkins. Hughes Aircraft Company, Fullerton, California. (Electronic Industries, Vol. 21, No. 2, February 1962, pp. 99-101, 15 refs.)

The effects of pulsed radiation on insulating materials, metals, semiconductor materials, gases, and other electronic materials is discussed.

161. RADIATION EFFECTS ON ELECTRONIC SYSTEMS. J.H. Levine and W.F. Ekern. (Electronics, Vol. 33, No. 17, 22 April 1960, pp. 69-70+)

Electronic components were assembled into a system and tested in a radiation field to determine radiation effects. The relative resistance of organic and inorganic materials is given in terms of energy absorbed (ergs/gm) for gamma rays and fast neutrons/cm$^2$. Radiation damage to electron tubes is caused largely by fracture of the metal-to-glass seal, particularly in tubes containing borosilicate glass. The irradiation data for communication-type systems are tabulated .

162. HOW RADIATION AFFECTS TUNNEL DIODES. (Electronics, Vol. 33, No. 19, 6 May 1960, pp. 32-33)

A 1-Gc cavity oscillator showed, for a given operating point a power output decrease of 1.5 db per $10^{16}$ neutrons/cm$^2$, becoming inoperative at $10^{17}$. A much more rapid rate of change was found for silicon units. At room temperature, the valley current increased by a factor of approximately two for an exposure of $9 \times 10^{15}$ neutrons/cm$^2$.

163. WHAT DESIGNERS SHOULD KNOW ABOUT TRANSIENT RADIATION. J. W. Clark and others. (Electronics, Vol. 34, 10 February 1961, pp. 62-65)

164. DESIGNING EQUIPMENT FOR NUCLEAR ENVIRONMENTS. P. Barratt. Pye Limited, Cambridge, Enland. (Electronics, Vol. 35, No. 11, 16 March 1962, pp. 51-57, 15 refs.)

How equipment and components are affected by radiation of high dosage, low dose rate and low rate of change of flux level radiation. Damage is illustrated with simple models of the structure of matter.

165. SUMMARY OF NUCLEAR RADIATION EFFECTS ON ELECTRONIC COMPONENTS AND SYSTEMS. J.E. Drennan and E.N. Wyler, Battelle Memorial Institute, Columbus, Ohio. (Electro-Technology, Vol. 67, No. 3, March 1961, pp. 132-134, 4 refs.)

Current nuclear-radiation data are reviewed for electron tubes, resistors, capacitors, relays, switches, terminals, transformers, transistors, and diodes.

166. SHIELDING ELECTRONIC CIRCUITS AGAINST NUCLEAR RADIATION. A. L. Long, S. M. Esposita and E. T. Hunter. (Electro-Technology, Vol. 67, June 1961, pp. 12-13)

167. EFFECTS OF GAMMA RADIATION ON CARBON RESISTORS. T. Nakai and T. Sakakibara. (ETJ Japan, Vol. 6, No. 2, 1961, pp. 43-47)

Deals with the effect of doses of up to $10^8$r on carbon resistors, the measurements being made after the components had been withdrawn from the radiation field. Non-coated pyrolitic resistors without helical coating increased in resistance with radiation dose, and this increase continued during several days after withdrawal from the radiation. Non-coated resistors exposed to 7.5 x $10^7$r increased by 2.85%, paint-coated resistors by 0.08%, non-coated components sealed in evacuated glass tubes by 0.17% and those in tubes filled with hydrogen by 0.12%. The respective increases of the temperature coefficient of resistance of those components were 0.84, 7.58, 11.11 and 17.58%. Composition resistors decreased by varying amounts within the range 0 to 20% and it appeared that this was due principally to deterioration of the synthetic resin binder under the radiation. Filament type composition resistors did not change by more than 0.4%.

168. IRRADIATION TESTS OF SELECTED TRANSDUCERS. E. W. Bradford. (General Dynamics, Ft. Worth, Texas, Contract AF 33(657)-7201, Document No. MR-N-265, NARF-61-24T, 15 December 1961, 58 p., 4 refs.) AD-269 411

A number of instrumentation transducers were irradiated for finding commercially available transducers that can be used in a radiation environment. The tests were made at ambient temperature and humidity conditions. The pickups were exercised during irradiation to simulate operating conditions. The pickups tested included differential transformers; fluid-damped and magnetic-damped velocity pickups; strain gages; piezoelectric accelerometers; bulk resistance thermometers; and inductive, strain-gage, and potentiometer pressure pickups. Potentiometer pressure pickups, magnetic-damped velocity pickups, and piezoelectric accelerometers operated satisfactorily in the radiation environment.

169. IRRADIATION TESTING OF ASBESTOS AND GLASS FIBER THERMOCOUPLE INSULATION. J. H. Sako, D. R. Green and J. C. Tobin. (General Electric Company, Hanford Atomic Products Operation, Richland, Washington, HW-60095, April 1959)

170. IRRADIATION OF PYROFILM RESISTORS. (General Electric, Atomic Products Division, Aircraft Nuclear Propulsion Department, Cincinnati, Ohio, DC-59-6-212, 17 June 1959)

171. EFFECTS OF INTENSE GAMMA RADIATION ON TURBOJET ACCESSORY SYSTEM SEALS AND HOSES. D. E. Barnett and W. G. Baxter. (General Electric Company, Atomic Products Division, Cincinnati, Ohio, Report XDC-59-12-76, 18 November 1959)

172. BASIC EFFECTS OF NUCLEAR RADIATION. J.R. Crittenden. Consultant-Radiation Effects, General Electric Company, Owensboro. Kentucky. (Electronic **Industries**, Vol. 21, No. 1. January 1962, pp. 102-106.)

More and more requirements for greater equipment reliability are being made. One of these is for more nuclear radiation tolerant equipment. To achieve this the engineer needs to know how radiation affects materials and electronic devices--how it is measured--where it comes from, and what it is.

173. REVIEW OF OUTER SPACE ENVIRONMENT. PART I. RADIATION ENVIRONMENT IN SPACE. R. A. Imobersteg. (General Electric Company)

174. RADIATION EFFECTS ON MICROWAVE DEVICES. E. P. Plankis. (General Electric Company, Schenectady, New York, Contract DA 36-039-sc-87253, Quarterly Progress Report No. 1, 1 July-30 September 1961, 30 September 1961, 33 p., 34 refs.) AD-268 636*

*No automatic release to Foreign Nationals.

The results of the literature search on Cu, Ti, forsterite ceramics, magnetic materials and the thoriated W emitter are stated. A summary and accompanying bibliography are given for each of these VTM materials. A description of the experimental procedure to be used for monitoring voltage-tunable magnetron (VTM) parameters during a pulse of nuclear radiation is included.

175. FIRST EXPERIMENT ON THE EFFECTS OF RADIATION PULSES ON ELECTRONIC CIRCUITS AND COMPONENTS. C. W. Perkins. (Hughes Aircraft Company, TM-506, February 1958)

176. SECOND EXPERIMENT ON PULSED NEUTRON EFFECTS. C. W. Perkins and others. (Hughes Aircraft Company, TM 622, September 1959)

177. THIRD EXPERIMENT ON PULSED NEUTRON EFFECTS. C. W. Perkins and others. (Hughes Aircraft Company, TM 623, October 1959)

178. BEHAVIOR OF SEMICONDUCTOR ELECTRONIC COMPONENTS WHEN EXPOSED TO NUCLEAR RADIATION. M. A. Xavier and S. A. Yefsky. (Inland Testing Laboratory, Morton Grove, Illinois, Contract AF 33(616)-3776, WADC TR 58-86, 212p.) AD 202 553L*

*Notice: Only Military Offices may request from Astia. Others request approval of Wright Air Development Center, Wright-Patterson AFB, Ohio. Attn: WCLK.

The results of $Co^{60}$ and reactor irradiations of semiconductor diodes representing 18 device types are summarized in terms of two or three representative samples of each type

179. SPACE RADIATION AS AN ENVIRONMENTAL CONSTITUENT. B. F. Badertscher and R. E. Hess, Battelle Memorial Institute, Columbus, Ohio. (Institute of Environmental Sciences, 1960 Proceedings on Hyper-Environments and Space Frontier, pp. 311-316)

Based upon the known charged-particle environment in the Van Allen belts and upon the effects of nuclear radiation on materials and components, it can be deduced that radiation damage to space vehicles will be small or negligible. Long-time exposures greater than a year might cause some damage. Since the basic structures provide some shielding, this time span might be extended by a considerable amount if the critical components are located properly.

180. RADIATION DAMAGE AND TRANSISTOR LIFE IN SATELLITES. J. M. Denny and D. Pomeriy. (IRE Proceedings, Vol. 48, May 1960, pp. 950-952)

181. RADIATION EFFECTS ON QUARTZ OSCILLATORS. O. Renius and D. Rees. (IRE Proceedings, Vol. 48, July 1960, p. 1340)

182. ELECTRONIC PARTS IN A HYPER-NUCLEAR ENVIRONMENT. L. B. Gardner and A. B. Kaufman. (IRE Transactions on Nuclear Science, Vol. NS-8, July 1961, pp. 35-44)

183. RADIATION EFFECTS TO FLIGHT CONTROL SYSTEMS. V. G. Smalley and P. Polishuk. (IRE Transactions on Nuclear Science, Vol. NS-9, No. 1, January 1962, pp. 260-279)

Nuclear-powered vehicles, pulse reactions from nuclear detonations, and space radiation are the sources of radiation considered in the development of techniques to design and evaluate high-temperature radiation-resistant flight control systems.

184. EFFECTS OF NUCLEAR RADIATION ON HIGH TEMPERATURE THERMISTORS. W. R. Owens. (IRE Transactions on Nuclear Science, Vol. NS-9, No. 1, January 1962, pp. 296-298)

High-temperature thermistors, 100 to 600°C, were tested before, during, and after irradiation in a radiation environment held constant at $2.2 \times 10^{10}$ $n_f/cm^2$-sec ($n_f$ = fast neutrons with energy >2.9 Mev) and $4.2 \times 10^{8}$ erg/g(C)-hr $\gamma$ for a period of 91 hours.

185. NUCLEAR ENVIRONMENTAL EFFECTS ON SPACE GUIDANCE AND CONTROL SYSTEMS. W. L. Fink. (IRE Transactions on Nuclear Science, Vol. NS-9, No. 1, January 1962, pp. 316-319)

The guidance and control system considered for analysis is a programmed inertial guidance unit with an astro-tracker for space coordinate corrections.

186. RADIATION EFFECTS ON INSULATION, WIRE, AND CABLE. C. J. Lyons and R. I. Leininger, Battelle Memorial Institute, Columbus, Ohio. (Insulation, Vol. 5, May 1959, pp. 19-26)

The authors provide an excellent summary of available information regarding radiation effects. Although each insulation material is discussed in as brief a manner as possible, nearly all significant points are covered. This article deals with radiation effects produced by $\gamma$-rays and fast and slow neutrons on specific elastomers and plastics.

187. INSULATION FOR A RADIATION ENVIRONMENT. PART I-INORGANICS. A. Bradley. (Insulation, Vol. 7, October 1961, pp. 23-31)

188. SOME EFFECTS OF PULSED NEUTRON RADIATION ON ELECTRONIC COMPONENTS. (IBM, Owego, New York, Contract AF 33(600)-31315, Final Report 1960, WADC TR 60-71, 78 p., 11 refs.) AD 232 286*

*Not releasable to Foreign Nationals.

The results are summarized of the investigations which were conducted on the effects of pulsed nuclear radiation on electronic components. Data are given on the effects of pulsed radiation on cables, capacitors, resistors, thyratons, voltage regulator tubes, and semiconductor circuits. Experiments which were performed on transistors and gas-filled capacitors are described.

189. STUDY OF EFFECT OF HIGH-INTENSITY PULSED NUCLEAR RADIATION ON ELECTRONIC PARTS AND MATERIALS (SCORRE). (IBM Corporation, Owego, New York, Contract DA 36-039-sc-85395, IBM No. 61-928-26, Quarterly Progress Report No. 4, 1 April-31 June 1961, 31 June 1961, 42 p.) AD-264 934*

*NO AUTOMATIC RELEASE TO FOREIGN NATIONALS.

The pulse responses of ferrite and tape-wound cores used for memory and logic applications were observed during exposure to bursts of nuclear radiation from the Sandia Pulsed Reactor (SPR). Test samples included ferrite toroid and two-aperture memory cores, ferrite and 4-79 mo-permalloy switch cores, and a tape-wound core used for magnetic logic applications. A static test of a small memory plane consisting of two-aperture ferrite cores was also conducted. No pulsed radiation effects were detected in most test samples. Two Disturb Test samples show variations that may be due to radiation on some undetermined test circuit malfunction. Mn-Zn ferrite switch cores show variations during the SPR burst, indicating that this material may be sensitive to pulsed radiation.

190. IRRADIATION DAMAGE IN GERMANIUM AND SILICON DUE TO ELECTRONS AND GAMMA RAYS. Julius H. Cahn, Battelle Memorial Institute, Columbus, Ohio. (Journal of Applied Physics, Vol. 30, August 1959, pp. 1310-1316)

The simple model for atomic displacements by electrons of Seitz and Koehler is used to calculate the total number of displaced atoms in Ge and Si due to electrons and gamma rays to energies up to 7 Mev. The calculations are compared to reported experiments in the literature. Electron damage at energies below 1 Mev requires the assumption of threshold energies less than 30 ev, while the higher energy electron damage data are fairly well explained by a 30-ev threshold. The measured gamma-ray cross sections for atomic displacements are an order of magnitude smaller than the calculated cross sections, even for a 30-ev threshold both for Si and Ge.

191. RADIATION EFFECTS ON RECOMBINATION IN GERMANIUM. Orlie L. Curtis, Jr. (Journal of Applied Physics, Vol. 30, August 1959, pp. 1174-1180)

The properties of recombination centers in Ge are obtained on the basis of lifetime data in conjunction with other information available. For recombination centers introduced by $Co^{60}$ gamma rays and fission neutrons, the recombination energy level position is placed at 0.20 ev below the conduction band. The room temperature hole-capture cross sections resulting are $1.1 \times 10^{-15} cm^2$ and $6 \times 10^{-15} cm^2$ for $Co^{60}$ gamma-ray and fission neutron irradiation, respectively.

192. SOME EFFECTS OF FAST NEUTRON IRRADIATION ON CARRIER LIFETIMES IN SILICON. R. W. Beck, E. Paskell and C. S. Peet. (Journal of Applied Physics, Vol. 30, September 1959, pp. 1437-1439)

Single crystal specimens of silicon have been exposed to fast neutrons from a reactor source to determine the room temperature effects of irradiation on carrier lifetimes. For highly n- and p-type material the approximate lifetime damage constants, defined as $1/\tau = 1/\tau i + \alpha\,\phi$, are found to be $\alpha n = 4.4 \times 10^{-7} (nvt)^{-1} x (sec)^{-1}$ and $\alpha p 1.2 \times 10^{-6} (nvt)^{-1} (sec)^{-1}$. Two possible positions of the dominant recombination level are 0.36 ev below the conduction band or 0.33 ev above the valence band. Further agreement with the value of p has been obtained by measuring high level lifetime in silicon junction diodes.

193. RESISTANCE OF RUBBERS TO THE ACTION OF IONIZING RADIATION (STOYKOST' REZIN K DEYSTVIYU IONIZIRUYUSHCHIKH IZLUCHENIY). A. S. Kuz'minskiy and Ye. V. Zhuravskaya. (Khimicheskaya Nauka i Prom, USSR, Vol. 4, No. 1, 1959, pp. 69-73)

194. PASSIVE COMPONENTS IN A HYPERNUCLEAR EVIRONMENT. Alvin B. Kaufman and Leonard B. Gardner. (Litton Systems, Inc., Woodland Hills, California, Contract AF 33(600)-41452, August 1961, 27 p., 5 refs., ASD TN 61-99) AD-269 239

The performance characteristics of passive components were examined dynamically during and after their exposure to a hypernuclear environment. The devices and materials irradiated were selected for test on the basis of analytical and literature research. The hypernuclear environment consisted of a fast neutron exposure in excess of 10 to the 16th power/sq cm above an energy of 2.9 Mev, accompanied by a gamma exposure in excess of 10 to the 11th power ergs/gm (C). This total integrated exposure was accumulated during 100 hours in a ground test reactor facility. The purpose was to find passive components suitable for application within the electronic systems of Litton's NGL inertial guidance platform. As such, the characteristics of resistive, capacitive, printed circuit board, and connector components and materials were among those determined.

195. RADIATION EFFECTS IN ELECTRICAL INSULATION. J. F. Hansen and M. L. Shatzen. (Lockheed Aircraft Corporation, 3rd Semiannual Radiation Effects Symposium, Vol. 5, 28-30 October 1958)

196. IRRADIATION OF AN AN/ARC-34 TRANSCEIVER. D. B. Howell. (Lockheed Aircraft Corporation, Marietta, Georgia, Report NR-80, February 1960)

197. RADIATION EFFECTS ON ELECTRONIC CIRCUITS. A. A. Beltran. (Lockheed Aircraft Corporation, Sunnyvale, California, Special Bibliography No. SRB-60-4, 31 August 1960, 43 p.) AD-250 955

The effects of radiation on electronic circuits, rather than radiation effects on materials and components, is the prime concern of this annotated bibliography. Reports and articles on designing for radiation environments, shielding, reliability, test procedures and results are included. No limitation was placed on the radiation type or environment. The literature on charged and uncharged particles as well as material on space and nuclear engine environments and nuclear detonations was covered.

198. EFFECTS OF ELECTROMAGNETIC FIELDS UPON INSTRUMENTATION COMPONENTS AND SYSTEMS. George R. Evans. (Lockheed Aircraft Corporation, Sunnyvale, California, Special Bibliography No. SB-60-27, 27 July 1960, 53 p.) AD-243 538

This search was undertaken to find what literature had been published on the subject of the effects of electromagnetic fields upon instrumentation components and systems. The search was originated to provide theoretical information and test reports to determine what effect (if any) flash deperming would have on Polaris submarines. An extensive survey was made in the subject areas of degaussing, deperming, electromagnetic fields, electromagnetic waves and radio interference.

199. EFFECTS OF HIGH ENERGY RADIATION ON INFRARED OPTICAL MATERIALS. AN ANNOTATED BIBLIOGRAPHY. George R. Evans and William E. Price. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 04(647)-564, Special Bibliography No. SB-61-25, May 1961, 43 p., 88 refs.) AD-262 429

A compilation of 88 abstracts of the effects of high energy radiation on infrared and other optical properties of germanium, silicon, germanium and silicon, fused and vitreous silica, glass, and quartz is presented. Effort was concentrated on finding changes in transmission properties but many peripheral subjects are included. The period covered is from 1950 to the present date. The abstracts are arranged by authors under each specific material. A corporate author index is also included. The following sources were checked: (1) Armed Services Technical Information Agency, (2) Institute of Metals, Journal, (3) Lockheed Missiles and Space Division, (4) Nuclear Science Abstracts, (5) Radiation Effects Information Center (Accession List), (6) Science Abstracts (Section A: Physics), (7) Semiconductor Electronics, (8) Semiconductors and Phosphors, and (9) Solid State Abstracts.

200. EFFECTS OF NUCLEAR RADIATION ON THE OPTICAL, ELECTRICAL, AND THERMO-PHYSICAL PROPERTIES OF SOLIDS. AN ANNOTATED BIBLIOGRAPHY. ADDENDUM TO SPACE MATERIALS HANDBOOK. Robert C. Gex. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 04(647)-673, Report No. 3-34-61-8, Special Bibliography No. SB-61-42, August 1961, 234 p.) AD 266 557

Annotated references (579) are presented on the effects of nuclear radiation on selected properties of a wide range of solid materials. The properties included are: optical absorptance, reflectance, transmittance and emittance; electrical resistivity and conductivity; refractive index; dielectric constant and strength; magnetic permeability; thermal conductivity; and heat capacity. Some studies of X-rays are included. Several classes of solids are specifically excluded; silicon and germanium, compound semiconductors and some other intermetallic compounds.

201. A CRITICAL SURVEY OF RADIATION DAMAGE TO CIRCUITS. W.W. Happ and S.R. Hawkins. (Lockheed Aircraft Corporation. Missile and Space Division, Report LMSD 5011, 1 July 1958, 35 p.) also(Third Semi-annual Radiation Effects Symposuim, Atlanta. Georgia, 28-30 October 1958, Electronics and Semi-conductors Papers, No. 39, 35 p.)

A critical survey was undertaken to investigate factors effecting circuit performance in the presence of damage producing radiations. Experimental work in progress consists of irradiating several types of circuits, such as multivibrators and blocking oscillators by gamma radiation with a 100-curie Cobalt-60 source. Causes of failure of the circuits tested thus far were traced primarily to the deterioration of semiconductor devices. This preliminary work is being used as a basis for planning investigations of other selected circuits, both under gamma and neutron irradiation.

202. EFFECTS OF RADIATION ON ELECTRONIC EQUIPMENT. T. R. Nisbet. (Lockheed Aircraft Corporation, Missile and Space Division, Sunnyvale, California, Technical Report LMSD-48498, 18 March 1959, 33 p.)

The different types of radiation are described with reference to their effect on electronic equipment, and methods are indicated for designing equipment to withstand a radiation environment. The effects of cosmic radiation on satellite instrumentation are considered and in an appendix the life expectancy of transistors in satellite applications is assessed at several years. Radiation damage to transistors and diodes is described with emphasis on circuit techniques for limiting the seriousness of the effects.

203. EFFECTS OF GAMMA RADIATION ON A TRANSISTOR RC PHASE-SHIFT OSCILLATOR. V. W. Moore, Jr. and others. (Lockheed Aircraft Corporation, Missile and Space Division, Sunnyvale, California, Report LMSD-288123, May 1960, 57 p.)

204. EFFECT OF NEUTRON IRRADIATION ON THE MAGNETIC PROPERTIES AND DEGREE OF ORDER OF MAGNETIC METAL ALLOYS. A. I. Schindler, E. I. Salkovitz, and G. S. Ansell. (Magnetism and Magnetic Materials Conference, Philadelphia, Pennsylvania, 17-20 November, 1958) also (Journal of Applied Physics, March, 1959)

205. RESISTORS, FIXED ULTRA-HIGH TEMPERATURE, RADIATION RESISTANT. D. R. Sivertsen. (P. R. Mallory and Company, Inc., WADC TR 59-270, July 1959) AD-215 857

206. PERFORMANCE OF RADIATION-RESISTANT MAGNETIC AMPLIFIER CONTROLS UNDER FAST NEUTRON AND GAMMA IRRADIATION. R. Sherwin and J. Montner. (Marquardt Corporation, Van Nuys, California, Preliminary Report, June-August 1961, 30 August 1961)

207. HOW RADIATION AFFECTS ENGINEERING MATERIALS. Richard E. Bowman, Radiation Effects Information Center, Battelle Memorial Institute. (Materials In Design Engineering, Vol. 52, No. 1, July 1960, pp. 119-134, 26 refs.)

Radiation has been added to the growing list of combined environments that the engineer must now consider. Here is an up-to-date summary of how it affects commonly used materials such as: Structural metals, Inorganic nonmetallics, Elastomers, Plastics, Organic fluids.

208. EFFECT OF SHIELD POSITION AND ABSORPTIVITY ON TEMPERATURE DISTRIBUTION OF A BODY SHIELDED FROM SOLAR RADIATION IN SPACE. Lester D. Nichols. (National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio, Technical Note D-578, January 1961, 41 p.)

An analytical study of temperature distributions on two disks subjected to solar radiation has been made. The effect on the temperature distribution of absorptivity, thermal conductivity, and the spacing between disks has been determined. The calculations show the possibility of using a movable shield as a temperature control device for a space vehicle.

209. IRRADIATION EFFECTS OF 22 AND 240 MEV PROTONS ON SEVERAL TRANSISTORS AND SOLAR CELLS. W. C. Hutten, W. C. Honaker, and J. C. Patterson. (National Aeronautics and Space Administration, Washington, D. C., Technical Note D-718, April 1961, 28 p.) AD 254 356

210. EARTH REFLECTED SOLAR RADIATION INPUT TO SPHERICAL SATELLITES. F. G. Cunningham. (National Aeronautics and Space Administration, Washington, D. C., Technical Note No. D-1099, October 1961, 9 p.) AD-265 255

A general calculation is given of the earth's albedo input to a spherical satellite, with the assumption that the earth can be considered a diffusely reflecting sphere. The results are presented in general form so that appropriate values for the solar constant and albedo of the earth can be used as more accurate values become available. The results are also presented graphically; the incident power is determined on the assumption that the mean solar constant is 1,353,000 ergs per sq cm per sec and the albedo of the earth is 0.34.

211. SPUTTERING OF A VEHICLE'S SURFACE IN A SPACE ENVIRONMENT. Jerome R. Redus. (National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama, Technical Note D-1113, June 1962, 35 p.)

A brief survey of current investigations of physical sputtering is given, from which estimates are made of the sputtering yields by constituents found in a vehicle's environment. The rates at which a vehicle's surface is sputtered by the earth's atmosphere, by radiation belts, and by solar corpuscular radiation are calculated. It is shown that the atmospheric sputtering constitutes a serious problem at low orbital altitudes and that the damage at 1 A.U. by solar corpuscular radiation is within an order of magnitude of that caused by micrometeorites. Recommendations are made regarding areas of investigation which are needed.

212. ULTRAVIOLET EFFECTS ON SPACE VEHICLE OPERATION IN ULTRAHIGH VACUUM ENVIRONMENT 22 SEPTEMBER 1960 TO 21 MARCH 1961 N. Beecher, W. Versluys, C. Accardo and P. Warneck. (National Research Corporation, Cambridge, Massachusetts, Contract AF 40(600)-906, AEDC-TDR-62-16, January 1962. 101 p., 33 refs.) AD-270 021

The effects of solar extreme UV radiation (1100 to 2000 Angstroms) is being studied by two methods: (1) an experimental study to find gross effects on polymers, paints, and metallic alloys used in space vehicle or space simulator construction; (2) a theoretical study to find the significance of photoemission and UV-induced outgassing on the performance of the space vehicle and the space simulator. A UV source was developed giving as effective output of 3 x 10 to the 15th power photons/sec in the range from 1100 to 1850 Angstroms with an ultrahigh vacuum system capable of operating in the low 10 to the -9th Torr (mmHg) range. Irradiation effects including outgassing of plastic samples of Mylar, Teflon, and Plexiglas are given.

213. ULTRAVIOLET EFFECTS ON SPACE VEHICLE OPERATION IN ULTRAHIGH VACUUM ENVIRONMENT 22 MARCH 1961 TO 22 SEPTEMBER 1961. W. Versluys and N. Beecher. (National Research Corporation, Cambridge, Massachusetts, Contract AF 40(600)-906, AEDC TDR 62-17, January 1962, 118 p., 20 refs.) AD 269 952

Analytical studies and experimental results are presented to show the gross effect of extreme UV radiation (110 to 1850 angstroms) on materials in ultrahigh vacuum. Experimental results on the irradiation of selected metals, plastics, and paints, indicated that the effects of 110 to 1850 angstrom radiation upon materials are small and are similar to effects caused by UV radiation of longer wavelengths. Only the high quantum yields for photo-emission are unique for the extreme ultraviolet range.

214. EFFECTS OF SPACE RADIATION ON ELECTRONIC COMPONENTS. D. J. Hamman, Battelle Memorial Institute. (National Symposium on The Effects of Space Environment on Materials, St. Louis, Missouri, 7-9 May 1962, 11p., 27 refs.)

There is little information available describing the effects of space radiation as such on electronic components. Semiconductors have been studied under simulated space radiation environment, i. e., proton and electron bombardment. Effects on other types of electronic components are extimated by comparison.

215. PROPERTIES OF PAINTS AS AFFECTED BY ULTRAVIOLET RADIATION IN A VACUUM. PART I. F.M. Noonan, A L. Alexander and J.E. Cowling. (Naval Research Laboratory, Washington, D.C., NRL Report 5503, 13 July 1960, 39 p.) AD-240 141

216. NUCLEAR RADIATION EFFECTS ON ELECTRONIC COMPONENTS. (North American Aviation, Inc., Space and Information Systems Division, Downey, California, Report SID 62-315, 15 March 1962, 36 p., 188 refs.)

This bibliography surveys the open and closed (document) literature during the years 1960 and 1961 on the subject of "Nuclear Radiation Effects on Electronic Components."
The arrangement is alphabetically by source - periodical title for articles, issuing agency for technical reports and scientific papers. An author index is included.

217. RADIATION PULSES AND ELECTRONICS. John W. Clark and Thomas D. Hanscome, Hughes Aircraft Company, Los Angeles. (Nucleonics, Vol. 18, No. 9, September 1960, pp. 74-77, 11 refs.)

Ionizing radiation can introduce spurious signals, distort normal ones and cause permanent malfunction. Inspecting responses to short pulses sometimes reveals the mechanisms involved.

218. RADIATION STABILITY OF CERAMIC MATERIALS. C. D. Bopp and R. L. Towns. (Oak Ridge National Laboratory, Atomic Energy Commission, ORNL-2188, 30 August 1958, p. 31)

219. EFFECTS INTERSTITIAL ELEMENTS ON WELDS IN ALPHA-BETA TITANIUM ALLOYS. W. J. Lewis, M. L. Kohn and G. E. Faukner. (Office of Technical Services, Washington, D. C., 31 March 1956, 87 p.) (Order from LC mi$4.80, ph$13.80) PB-129 436

Welding studies were conducted to determine the effects of C, N, and O on the mechanical properties of inert-gas metal-arc-welded joints in selected experimental alpha-beta titanium alloys. In practically all cases, these elements had a deleterious effect on the ductility and toughness of welds. A study also was made to determine the effects of H on the mechanical properties of titanium-iron alloys. Deleterious effects were observed on the mechanical properties of the base metals and welds of the Ti-1.5Fe and Ti-3.0Fe alloys due to added H.

220. RADIATION TOLERANCE OF SELECTED GROUP OF COAXIAL CABLES. P. E. Proulex and others. (Sandia Corporation, New Mexico, Report TM-400-59(16), 18 January 1960)

221. STUDY OF PULSE VOLTAGES DEVELOPED BY COAXIAL CABLES DURING PULSED NEUTRON IRRADIATION. J. M. Caller. (Sandia Corporation, Albuquerque, New Mexico, Report TM-62-61(14), April 1961, 27 p.)

222. EFFECTS OF GAMMA RAY AND NEUTRON IRRADIATION ON COMPOSITION RESISTORS AND HIGH MEGOHM RESISTORS. T. Nakai and T. Sakakibara. (Sci. Pap. Inst. Phys. Chem. Res., Japan, Vol. 54, June 1960, pp. 170-176)

Deals with two types of composition resistor, one composed of carbon granules, a filler and a synthetic resin binder, while the other consists of a small glass tube covered with a thin film of carbon granules. The high-megohm resistor is of the filament type. The solid types of resistor change in resistance when exposed to radiation, but the filament types are fairly radiaton-proof. When exposed to 10 r of gamma radiation, the solid-type resistors decreased about 8% (USA pattern) and by 12-16% (Japanese pattern). Filament-type resistors changed by less than 1%, while high-megohm resistors decreased by amounts of up to 60%. Neutron irradiation produced similar effects.

223. EFFECT OF NUCLEAR EXPLOSIONS ON RADIO COMMUNICATION. H. P. Williams. (Shape Air Defense Technical Centers, The Hague, Technical Memo 1960/TM-5, July 1960) AD-241 487

224. RADIATION EFFECTS OF 40 AND 440 NEV PROTONS ON TRANSISTORS. William C. Hulten, National Aeronautics and Space Administration, Langley Research Center, Langley Station, Virginia. (Society of Aerospace Material and Process Engineers Symposium, St. Louis, Missouri, 7-9 May 1962, 42 p.) (OTS ph$4.60, mf$1.46)

Experimental results are presented covering the data collected before, during, and after the bombardment of several types of transistors with 40 and 440 Mev protons. The data indicate a proton energy, as well as a transistor frequency dependence on degradation of the various parameters measured. A number of figures are presented showing the degradation of the gain of the transistors as a function of integrated proton flux.

225. ACTION OF IONIZING RADIATIONS ON CABLE RUBBERS. G. I. Dubrovin, Yu. M. Malinskii and V. L. Karpov. (Soviet Rubber Technology, Vol. 18. No. 7. 1959. pp. 6-10)

226. EFFECTS OF NUCLEAR RADIATION ON SOME COMMON MATERIALS AND ELECTRONIC COMPONENTS. Newell Hart Smith. (Space Technology Laboratories, Los Angeles, California, GM-TR-o165-00358, 4 February 1958, 24 p., 18 refs.) AD 225 788

This report has been written to provide guidance for those doing preliminary design of equipment to be exposed to nuclear radiation. It is based upon a review of many of the documents from the extensive literature on radiation damage, and presents information from the literature concerning radiation damage to a few common materials and to typical electronic equipment. In addition, an example illustrating the way in which this information may be useful for space vehicle desugb us aksi guveb.

227. RESEARCH ON EFFECTS OF NUCLEAR RADIATION ON DIELECTRICS AND MAGNETICS. S.I. Taimuty and C.A. Rosen. (Stanford Research Institute, Menlo Park, California, Contract AF 19(604)-4141, Scientific Report No. 1, AFCRC TN-58-572, Quarterly Report No. 1, July 1958-September 1958, 31 October 1958, 10 p.) AD-160 886

Preliminary results of a survey of the literature on the effects of nuclear radiation on magnetic alloys, ferroelectric materials, and quartz are presented. Of these materials, quartz has received the most attention, followed by magnetic alloys, ferrites, and ferroelectric materials, in that order.

228. RESEARCH ON EFFECTS OF NUCLEAR RADIATION ON MAGNETIC AND DIELECTRIC MATERIALS. S. I. Taimuty and C. A. Rosen. (Stanford Research Institute, Menlo Park, California, Contract AF 19(604)-4141, Scientific Report No. 3, AFCRC TN 59-990, 10 November 1959) AD 232 109 (see also) AD 160 886 and AD 220 630

As the first part of a project to study the effect of nuclear radiation on magnetic and dielectric materials, three instruments have been developed to measure radiation-induced changes in the properties of magnetic and ferroelectric materials. One is a magnetic hysteresigraph for recording hysteresis loops in toroidal magnetic samples at frequencies of 400 cps to 100 kcps. The second is an apparatus employing a bridge technique for small-signal magnetic permeability measurements at frequencies of 15-640 kcps. The third is a ferroelectric hysteresigraph for recording hysteresis loops in ferroelectric materials at frequencies of 60-10.000 cps.

229. ON THE RADIATION HAZARDS OF SPACE FLIGHT. J. A. Van Allen. (State University of Iowa, Report SUI-59-7, May 1959)

230. RADIATION MEASUREMENTS TO 658,300 KILOMETERS WITH PIONEER IV. J. A. Van Allen and L. A. Frank. (State University of Iowa, Report SUI-59-18, August 1959)

231. NUCLEAR RADIATION TESTS CONDUCTED ON HIGH-TEMPERATURE RADIATION RESISTANT COMPONENTS AND CIRCUITRY. R. K. Lyons. (Systems Research Laboratories, Inc., Dayton, Ohio, Contract AF 33(600)-38141, BRC-13565, Progress Report No. 107-12, 10 November 1960)

232. PERFORMANCE OF A SPECIAL DIFFERENTIAL TRANSFORMER AND AN EDDY CURRENT COIL IN A HIGH GAMMA FLUX ENVIRONMENT. G. J. Pokorny and J. E. Ayer. (University of Chicago, Argonne National Laboratory, Lemont, Illinois, ANL-5988, W-31-109-Eng-38, July 1959)

233. EFFECTS OF PULSED NEUTRONS OF INFRARED DETECTORS. J. C. Marshall. (U. S. Air Force Institution of Technology, Wright-Patterson Air Force Base, Ohio, Master's Thesis, Report No. GA/Phys/60-4, August 1960) AD-246 465

234. STUDY OF THE DYNAMIC CHARACTERISTICS OF THE TUNNEL DIODE AS AFFECTED BY ELECTRON BOMBARDMENT. D. L. Phillips. (U. S. Air Force Institution of Technology, Wright-Patterson Air Force Base, Ohio, Report GE/EE/60-12, August 1960) AD 246 473

235. THEORETICAL AND EXPERIMENTAL STUDIES CONCERNING RADIATION DAMAGE IN SELECTED COMPOUND SEMICONDUCTORS. L. W. Aukerman, E. M. Baroody, R. D. Graft and T. S. Shilliday. (United States Air Force, Office of Aerospace Research, Aerospace Research Laboratory, ARL 62-343, May 1962, 62 p., 42 refs.)

236. THEORETICAL STUDY OF BURST INDUCED TRANSIENT RADIATION EFFECTS IN BASIC ELECTRONIC CIRCUITS. J. E. Bell and K. R. Walker, Hughes Aircraft Company, Culver City, California. (U. S. Air Force Special Weapons Center, Technical Report 61-40, 15 May 1961, 280 p.) AD 262 490

237. RADIATION HEAT TRANSFER ANALYSIS FOR SPACE VEHICLES. APPENDIX A - TABLES OF EMISSIVITY AND ABSORPTIVITY. APPENDIX B - PLANETARY THERMAL EMISSION AND PLANETARY REFLECTED SOLAR RADIATION INCIDENT TO SPACE VEHICLES. J. A. Stevenson and J. C. Grafton. (U. S. Air Force, Systems Command, Aeronautical Systems Division, Flight Accessories Laboratory, ASD TR 61-119, Part I, December 1961, 420 p., 113 refs.)

Discussion of the problems associated with the analysis of heat transfer in space. The basic principles of thermal radiation are reviewed, and the theory of radiation heat transfer is discussed with particular reference to the thermal radiation environment in space. Several available methods of radiation heat transfer are outlined, and the accuracy and versatility of the radiosity analog network method is demonstrated. An IBM 7090 program is presented which permits calculation of space-vehicle shell-temperatures, as well as of the incident radiant energy acting on a vehicle. This program is shown to accurately simulate any elliptical or circular satellite orbit. To facilitate the analysis of radiation heat transfer, a wide range of calculated configuration factor data is tabulated.

238. SEMICONDUCTOR DIODE PERFORMANCE IN NUCLEAR RADIATION ENVIRONMENTS. Appendix A-GENERAL PURPOSE DIODE INSTRUMENTATION. Appendix B-MICROWAVE INSTRUMENTATION AND SHIELDING REQUIREMENTS. Appendix C-NEUTRON FLUX SPECTRA AND EXPOSURE MEASUREMENTS. H. G. Hamre, R. C. Barrell and W. N. McElroy. (United States Air Force, Systems Command, Aerospace Systems Division, ASD TDR 62-12, May 1962, 87 p., 21 refs.)

Determination of the performance characteristics for two types of general purpose diodes, and for five types of microwave diodes, in radiation environments equivalent to at least 1,000 hours exposure to $10^{10}$ neutron/cm$^2$ -sec. and 2 x $10^5$ rad/hr. None of the units studied show satisfactory performance characteristics after this exposure, although the germanium IN263 point-contact diode is degraded less than others investigated, and still exhibits measureable properties following the exposure. Results, although not conclusive, seem to indicate that energizing the microwave mixers at X-band (9375 mc) during radiation is helpful in prolonging the life on the units.

239. TRANSIENT EFFECTS OF PULSE RADIATION ON ELECTRONIC PARTS. A. L. Long and H. J. Degenhart. (U. S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey, 20 January 1959)

240. RADIATION DAMAGE -- SURVEY OF THE FIELD. A. L. Hanzel. (U. S. Naval Ordnance Laboratory, Research Department, Corona, California, Technical Memorandum 42-30, May 1959)

241. RADIATION DAMAGE THRESHOLDS FOR PERMANENT MAGNETS. R. S. Sery, R. H. Lundsten and D. I. Gordon. (U. S. Navy, Naval Ordnance Laboratory, White Oak, Maryland, Report TR 61-45, 18 May 1961, 35 p.)

242. X-RAY DIFFRACTION CORRELATION BETWEEN RADIATION DAMAGE AND COMPOSITION OF RUBBER. W. E. Shelberg and L. H. Gevantman. (U. S. Navy, Naval Radiological Defense Laboratory, San Francisco, USNRDL-TR-356, NS-033-200, AEC, 12 August 1959) AD 228 835

243. EFFECT OF RADIATION UPON CERAMIC-BANDED STRAIN GAGES. N. J. Rendler and R. C. Smith. (U. S. Navy, Naval Research Laboratory, Washington, D. C., Report NRL-5450, 20 April 1960)

244. RADIATION EFFECTS: APPARATUS FOR IN-PILE ELECTRICAL MEASUREMENTS AND EFFECT OF RADIATION UPON STRAIN GAGE INSULATION COMPONENTS. N. J. Rendler. (U. S. Navy, Naval Research Laboratory, Washington, D. C., NRL Report No. 5674, 2 October 1961, 30 p.) AD-265 773

Test facilities were developed for a series of in-pile experiments to be inserted in the reactor core immediately adjacent to the fuel element assembly of the NRL pool-type reactor. The apparatus design includes provision for in-pile electrical measurements, in-pool assembly and disassembly of experiments, temporary storage in the pool and transfer capability for post-irradiation operations in the hot cell. The program of study of the effects of nuclear irradiation upon the components of the ceramic bonded strain gage was continued with evaluation of the electrical resistance of lead wire insulation. The insulation resistance between electrical conductors was maintained at values greater than 10,000 megohms during an exposure to an integrated fast neutron flux. The high values of resistance were obtained with a ceramic-type wire insulation tested in an inert atmosphere of dry helium.

245. PROPERTIES OF PAINTS AS EFFECTED BY ULTRAVIOLET RADIATION IN A VACUUM--PART 2. D. E. Field, J. E. Cowling and F. M. Noonan. (U. S. Navy, Naval Research Laboratory, Washington, D. C., Projects RR 007-08-44-5508 and SF 015-07-02-3349, NRL Report 5737, 8 March 1962, 28 p., 10 refs.) AD 273 716

Organic coatings are being studied as one possible means of achieving temperature control within space vehicles. However, their usefulness in the space environment may be limited by their physical and chemical stability in space. It is shown that the optical properties of most organic coatings are changed on exposure to intense ultraviolet radiation in high vacuum. Of the reflective pigments studied, those containing zinc sulfide and leafing aluminum are shown to be most stable to this radiation.

246. PROCEEDINGS OF THE CONFERENCE ON TRANSIENT EFFECTS OF PULSED NUCLEAR RADIATION ON ELECTRONIC EQUIPMENT. V. E. Bryson and A. F. Vetter. (Wright Air Development Center TR 60-281, August 1959, SECRET)

247. STUDIES ON THE PROTECTIVE ULTRAVIOLET ABSORBERS IN A SPACE ENVIRONMENT. R. C. Hirt and R. G. Schmitt, American Cyanamid Company, Central Research Division, Stamford, Connecticut. (Wright Air Development Division, Wright-Patterson Air Force Base, Ohio, WADD TR 60-773) also (Coatings for the Aerospace Environment, Proceedings of Meeting, Wright Air Development Division, 9-10 November 1960, p. 273)

The purpose of this investigation is to study the effects of a space environment on the protective ultraviolet absorbers, with major emphasis on their stability to evaporation and short wavelength ultraviolet radiation under a high vacuum. The requirements for an effective ultraviolet absorber are that it absorb strongly in the wavelength region to which the plastic is photosensitive, that it be relatively stable to this radiation, and that it be compatible with the material in which it is used. Certain benzophenone and benzotriazole derivatives have these desirable properties and have provem themselves invaluable for many terrestrial applications.

SECTION B

**Micrometeorites**

248. MICROMETEORITE MEASUREMENTS FOR THE MIDAS II SATELLITE (1960 ZETA I). R. K. Soberman and L. Della Lucca. (Air Force Cambridge Research Laboratories, Bedford, Massachusetts, Report No. AFCRL-1053, GRD Research Notes No. 72, November 1961, 7 p., 5 refs.) AD-268 556

Five micrometeorite sensing devices were carried on board the Midas II (1960 Zeta 1) satellite which was launched into an approximately 500-km circular equatorial orbit on 24 May 1960. The five devices consisted of three acoustic detectors and two wire-grid detectors. Data were obtained for four partial orbits. These data were recorded in real time. There were no breaks in the wire grids which could record impacts of particles larger than 10 microns. Sixty-seven impacts were recorded on the acoustic detectors which had a momentum threshold of 3 x 10 to the -4th power gm cm/sec and a total area of 0.0686 sq m. These results indicate a flux of 0.25 sq m sec of particles 5 microns in diameter or larger if one assumes a mean velocity of 15 km/sec and a density of 3 gm/cc for the particles. The discrepancy between acoustic and wire-grid data is discussed.

249. METEORIC EFFECTS ON ATTITUDE CONTROL OF SPACE VEHICLES. J. B. White, National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Alabama. (ARS Journal, Vol. 32, No. 1, January 1962, pp. 75-78, 5 refs.)

To design adequately an attitude control system for an orbital vehicle, it is necessary to know the magnitudes of the disturbances acting on the vehicle. Numerous papers are available dealing with disturbances resulting from Earth's gravitational, magnetic and electric fields, aerodynamic drag, and solar radiation pressure, but little has been done to determine attitude disturbance due to meteoric bombardment. The purpose of this paper is to develop general methods for determining meteoric disturbances for any known vehicle configuration; the methods are then applied to the 24-hr communication satellite for illustrative purposes. Probable disturbance is in the order of $10^{-3}$deg/sec. Calculated impact density agrees favorably with that measured by Explorer I and a Vanguard.

250. DESIGN RECOMMENDATIONS FOR SPACE VEHICLE COMPONENTS WITH REGARD TO THE METEOROID ENVIRONMENT. Gerald J. Cloutier. (AVCO Corporation, Research and Advanced Development Division, Wilmington, Massachusetts, Contract AF 04(647)-305, Technical Memo No. RAD-9-TM-60-59, 16 September 1960, 16 p.) AD-243 227

This report combines existing data on the number, mass, density, and velocity of meteoroids with analytically determined formulas for hypervelocity impact to determine the frequencies of puncturing of various thicknesses of aluminum and steel plates. Then the concept of reliability is introduced to provide basis for the preliminary design of exposed surfaces in space. An estimate of the surface damage an object in space will sustain due to meteoroid bombardment is made, using as a criterion the percent of total surface area which is affected. Finally, there is a discussion of methods of protecting various components of space vehicles from meteoroid damage.

251. INTERNATIONAL SYMPOSIUM ON THE PHYSICS AND MEDICINE OF THE ATMOSPHERE AND SPACE, SECOND, SAN ANTONIO, TEXAS, 10-12 NOVEMBER 1959, Otis O. Benson, Jr. and Hubertus Strughold, Editors. (John Wiley & Sons, New York, 1960, 645 p.)

Contents include an article entitled, "Effects of interplanetary dust and radiation environment on space vehicles," which has 37 references.

252. METEORITIC DUST AND GROUND SIMULATION OF IMPACT ON SPACE VEHICLES. Donald H. Robey, Convair-Astronautics, A Division of General Dynamics Corporation, San Diego, California. (British Interplanetary Society, Journal, Vol. 17, No. 1, January-February 1959, pp. 21-30, 37 refs.)

A general discussion of meteoritic dust is presented and deductions pertaining to the physical properties and probable speeds are given. Thus, the siliceous (glass-like) and magnetic (iron-nickel) spherules, which are found on the ground, are believed to originate at meteor altitudes from vaporized meteorites. A large quantity of smaller sized dust is believed to be cometary, either arriving directly from comets, etc., per se, or indirectly from exploding or disintegrating meteoroids. The possibility that a portion of the influx of meteoroids may contain a sizeable percentage of frozen molecular fragments has influenced the results. For example, from this hypothesis, the possibility of a dust cloud surrounding the Earth and extending out for several thousand miles has been suggested. Also, the correlation between prominent meteor showers and excessive rainfall, snow cover and cirrus cloud, as noted by Bowen, can be explained on this basis.

253. EFFECTS OF MICROMETEORITES ON SPACE VEHICLES. AN ANNOTATED BIBLIOGRAPHY. ADDENDUM TO THE SPACE MATERIALS HANDBOOK. J. B. Goldmann and W. L. Hollister. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 04(647)-673, Report No. 3-34-61-5, Special Bibliography No. SB-61-37), July 1961, 46 p., 116 refs.) AD-263 821

The references included in this publication were gathered to present information on the effects of cosmic dust, micrometeorites, and meteorites on space vehicles. The erosive effects of micrometeorites and cosmic dust are included. Also included are the penetration effects of meteorites. Information on the effects of erosion and penetration on thermal contract surfaces, effects on structures and effects on optical devices were included. Theoretical and experimental research on erosion and penetration were also included. References are arranged alphabetically by author.

254. PRELIMINARY INVESTIGATION OF IMPACT ON MULTIPLE-SHEET STRUCTURES AND AN EVALUATION OF THE METEOROID HAZARD TO SPACE VEHICLES. C. Robert Nysmith and James L. Summers. (National Aeronautics and Space Administration, Washington, D. C., Technical Note D-1039, September 1961, 27 p.)

Small pyrex glass spheres, representative of stony meteoroids, at velocities to 11,000 ft/sec were fired into 2024-T3 aluminum alclad multiple-sheet structures to evaluate their effectiveness for shielding spacecraft from meteoroids. These tests indicated that the penetration resistance of a structure of constant weight per unit area is improved by: (1) increasing the number of sheets while keeping the total sheet thickness constant, (2) increasing the spacing between the sheets, and (3) filling the space between the sheets with a light filler material. The penetration resistance is increased by a factor of 1.75 when a single sheet of material is divided into two sheets space 1/2 in. apart. With a 1 in. spacing between the sheets, resistance is increased by a factor of about 2.2 over the single sheet of the same total material thickness. Four-sheet are about 1.2 times as effective as the two-sheet structures for both 1/2 and 1 in. spacings.

255. METEORITIC HAZARD OF THE ENVIRONMENT OF A SATELLITE. J. E. Duberg. (National Aeronautics and Space Administration, Washington, D. C., Technical Note D-1248, May 1962, 34 p., 23 refs.)

Review of the current knowledge of meteorites, their composition, and frequency of occurrence. A meteoroid flux as a function of mass that has been proposed by Whipple is compared with the direct measurements obtained to date by rockets, satellites, and space probes. On the assumption of a Poisson distribution for the probablilty of impacts and a penetration law which represents a mean of those proposed for high-velocity impact, the probability of penetration of Earth satellite surfaces is obtained.

256. STUDY OF HYPERVELOCITY IMPACT OF PARTICLES ON MATERIALS. (North American Aviation, Inc., Missile Division, Downey, California, Final Summary Report MD-59-114, June 1960, 35 p.)

In order to gain information on the probable effects of micrometeorite impacts upon spacecraft construction materials, a hypervelocity gun system was developed. This system, accelerating spherical projectiles by aerodynamic drag in the flowing high-temperature gas generated by high-energy capacitor discharge in a partially confined mass, has produced impact data at velocities up to 9.5 km per sec (31,000 fps). The generated plasma flow through the accelerating channel does not disrupt 100 $\mu$ diameter borosilicate glass spheres during the process. Sphere integrity is monitored in flight by a sensitive light-scattering technique.

Quantitative target damage is reported for 2024-0 aluminum, both clad and bare, and for LA 141 magnesium-lithium alloy. Both crater depth-to-diameter ratios and crater-to-projectile volume ratios are reported. The full potential of the accelerating technique has not yet been reached.

257. EFFECT OF MICROMETEORITE COLLISIONS ON SPHERICAL WIRE-MESH PASSIVE REFLECTORS. Edward Bedrosian. (Rand Corporation, Santa Monica, California, Contract NASr-21, RM-3274-NASA, August 1962, 12 p., 6 refs.)

This Memorandum investigates the possible effects of micrometeorites in reducing the useful lifetime of a spherical wire-mesh passive-reflector communications satellite. Theoretical conditions are postulated under which a wire composing part of the mesh might be severed by a hyper-velocity collision with a micrometeorite. This criterion, taken with the known flux of micrometeorites, is used to compute the probability that such collisions will degrade the electrical performance of such a reflector. It is concluded that they will not significantly effect its useful lifetime.

258. HYPERVELOCITY PARTICLE EFFECTS ON MATERIAL. Victor E. Scherrer and Robert R. McMath. (Technical Operations, Inc., Burlington, Massachusetts, Contract AF 33(616)-8423, Report No. TO-B 62-3, Quarterly Progress Report No. 2, 31 December 1961, 16 p.) AD-272 669

The range of projectile densities was extended from 0.9 to 2.2 with the successful acceleration of polyethylene, Mylar and Teflon particles. Velocities in excess of 32,000 ft/sec were achieved with Mylar particles 10 mils thick, 0.375 and 0.5 in. diam., and weighing 24.7 and 44 mg. respectively. A single particle impact was achieved with the smaller particle. Successful projection of 11-mg Mylar particles to velocities of 20,000 to 62,800 ft/sec was achieved. Target materials included lead, lucite, and wax. Laboratory equipment includes an energy-storage system consisting of a parallel connection of eight 1-microfarad capacitors discharged by a hypervelocity gun, a streak camera, a high-intensity pulsed backlighting source, photomultiplier tubes, and crater profile tracing equipment.

259. RESEARCH ON THE EFFECTS OF COLLISIONS OF SMALL PARTICLES WITH BODIES MOVING AT HYPERSONIC SPEED. PART III. EROSION AND HEAT TRANSFER EFFECTS. G. Whitnah, J. Upton, R. Griffith, G. Morfitt, G. Jorgenson and D. Rotenberg, General Mills, Inc., Mechanical Division, Research Department, Minneapolis, Minnesota. (Wright Air Development Center, Technical Report 58-498, Part III, December 1960, 76 p.) AD-254 021

A small number of surface pits is extremely effective in increasing the heat transfer to a body under the flow conditions of atmospheric re-entry. The effects of distributed surface roughness on convective heat transfer to spherical surfaces were studied, using copper models, three with surfaces uniformly roughened with hemispherical pits, and one with a smooth surface. Tests were conducted in a blow-down flow channel which simulated aerodynamic characteristics of hypersonic flight. Local heat transfer coefficients were obtained with specially developed flux meters installed in the models. Data are presented for 72 runs of approximately 20 sec duration. Stagnation pressures of either 2.6 atm or 3.9 atm were used with each model. The average stagnation temperature was 417 $\pm$ 11 K for all runs.

SECTION C

# Temperature

260. ELEVATED TEMPERATURE BEHAVIOR OF FIBERS. Stanley Schulman. (Aeronautical Systems Division, Directorate of Materials and Processes, Wright-Patterson Air Force Base, Ohio, Project No. 73201, Report on Fibrous Materials for Decelerators and Structures, July-October 1960, August 1961, 12 p., WADD TN 60-298) AD-267 360

A study was conducted to determine the mechanical behavior of fibers at high temperatures for varied periods of time. These fibers are candidate materials for decelerators, and expandable and rigid structures for satellites or space vehicles. Besides condition of extremes of temperature, these fibers will have to be capable of operation under shock, vibration, solar and cosmic radiation and related aerospace environments. These high temperature fibers were evaluated in filament form at temperatures ranging from 70 F (65% relative humidity) to 2000 F. Since fibers normally were of diameters as low as 0.0003 in., special equipment and procedures were designed to obtain their basic properties.

261. DEVELOPMENT OF MAGNET WIRES CAPABLE OF OPERATION AT 850 DEGREES C AND UNDER NUCLEAR RADIATION. Wesley W. Pendleton and John P. Fekete. (Anaconda Wire and Cable Company, Muskegon, Michigan, Contract AF 33(616)-7473, Interim Scientific Report No. 3, 1 March-30 June 1961, 30 June 1961, 26 p.) AD-267 176*

*No automatic release to Foreign Nationals.

Available single metal clad conductors are not suitable for 850 C operation because of excessive migration of cladding and Cu core. It is possible to produce a conductor with a metallic oxide separator between sheath and core which may stopy alloying activity. Tensile properties of Cu are seriously affected by prolonged heating at 850 C. Explosion techniques achieve complete consolidation of plasma-jet sprayed metal coatings. Thermospray techniques where the metallic oxide is fed into a flame at 5000 F were successful in forming the separator on Cu rod prior to insertion in the cladding tube. Vacuum plus 850 C produces visible evaporation of copper. Nucleated glasses suitable for wire insulation were produced. A new technique for carbon removal was developed utilizing oxidation agents. Thermospray methods were applied to encapsulating coils with limited success.

262. EFFECTS OF THERMAL ENVIRONMENT ON LAMINATED PLASTICS. S. W. Place. (Applied Plastics, Vol. 3, February 1960, pp. 44-46)

The effects of extreme temperature and humidity conditions on characteristics important in electrical and mechanical applications are briefly discussed.

263. SURFACE EFFECTS ON SPACECRAFT MATERIALS. Francis J. Clauss, Editor. (John Wiley & Sons, New York, 1960, 404 p.)

Presents papers given at a symposium held at Palo Alto, California, 12-13 May 1959, on the effect of surface thermal-radiation characteristics on the temperature-control problem in satellites; temperature control of the Explorers and Pioneers, coatings for space vehicles; emissivity of materials near room temperature. Vanguard emittance studies at NRL; emissivity, absorptivity, and high-temperature measurements at Armour Research Foundation; material sublimation and surface effects in high vacuum; surface phenomena and friction; measurements of extreme ultra-violet solar radiation and associated photoelectric emissions from solids; interplanetary dust distribution and erosion effects; atomic and molecular sp ttering; and other problems.

264. NEW EXTREME-TEMPERATURE SILICONE ENCAPSULANT. J. B. Allen, M. E. Nelson and R. L. Spraetz. (Electrical Manufacturing, Vol. 63, No. 1, January 1959, pp. 10-11)

265. EFFECTS OF TEMPERATURE ON HIGH-FREQUENCY TRANSISTORS. C. R. Gray and T. C. Sowers. Lansdale Division, Philco Corporation, Lansdale, Pennsylvania. (Electro-Technology, Vol 70, No. 1, July 1962, pp. 104-106)

Variations in the parameters power gain, bandwidth, noise figure, power output and frequency shift are caused by temperature changes of the high-frequency germanium diffused-base transistor. A number of measurements have been made which relate high-frequency transistor parameters )Philco MADT type) to ambient temperatures ranging from 60 to +80 C.

266. THERMAL PROBLEMS OF SATELLITES. G. H. Heller. (Fifth Sagamore Conferance on Ordnance Materials) AD-205 880

267. HOW ENVIRONMENT AFFECTS MAGNETIC RECORDING TAPE. Clarence B. Stanley. (IRE Transactions on Space Electronics and Telemetry, Vol. SET-6, No. 1, March 1960, pp. 19-24)

The increasing emphasis on higher and higher operating and/or storage temperatures for data acquisition apparatus requires a critical appraisal of the behavior of available magnetic recording tapes as their rated operating limits are approached or exceeded. Critical temperatures and observed effects are described.

268. WHAT ARE THE COMBINED EFFECTS OF TEMPERATURE AND VERY HIGH PRESSURE ON METALS? R. B. Fischer, Battelle Memorial Institute, Columbus, Ohio. (Journal of Metals, Vol. 12, September 1960, pp. 700-702)

The inception of high-pressure, high-temperature operation has opened many new avenues of investigation. The article discusses the possible effects of both on electrical resistance, ductility, hardening, and other mechanical and structural properties of metals.

269. THERMAL RADIATION EFFECTS ON DECELERATOR MATERIALS. Peter E. Glaser and Sabino Merra. (Arthur D. Little, Inc., Cambridge, Massachusetts, AF 33(616)-7692, Technical Documentary Report ASD-TDR-62-185, February 1962, 51 p., 16 refs.) AD 273 872

An investigation was made of the effects of thermal radiation on the strength of fibrous materials used in deceleration devices. Approximately 400 tests were run on webbing and tape materials of various strengths. The work involved the development of laboratory equipment to simulate the thermal shock of a nuclear blast, flux redistributors, a high-velocity air supply, and a static loading device.

270. ULTRA HIGH TEMPERATURE, RADIATION RESISTANT, PRECISION POTENTIOMETERS. A. S. Halpern. (Markite Company of New York, New York, Quarterly Report No. 3, 10 June 1960) AD-245 807L

271. HOW LOW TEMPERATURES AFFECT NINE HIGH STRENGTH ALLOYS. R. L. McGee, J. E. Campbell, R. L. Carlson and G. K. Manning. (Materials in Design Engineering, Vol. 50, November 1959, pp. 106-107)

Recent development in the aircraft and missile fields require the use of materials at extremely low temperatures. The main reason is that liquid propellants can be retained only at temperatures of -297 F (boiling point of liquid oxygen) or lower. Nine steels, aluminum and magnesium alloys, and titanium alloys, imporyant in airborne structures because of their excellent strength-weight ratios, were tested at four temperatures ranging from room to -423 F and the results tabulated and explained. Conventional tensile, notched tensile, hardness, and impact tests were made.

272. HIGH-TEMPERATURE PROPERTIES OF CERAMICS AND CERMETS. E. Glenny and T. A. Taylor. (Powder Metallurgy, Nos. 1/2, 1958, pp. 189-226)

Evaluation of the major properties involved, viz., creep strength, fatigue strength, resistance to thermal fatigue (i.e., to repeated thermal shocks), oxidation-resistance, and impact-resistance. The materials evaluated include oxides, oxide-metal cermets, carbides, carbide-metal cermits, Mo disilicide, and Si nitride.

273. HIGH TEMPERATURE LUBRICATION IN THE PRESENCE OF NUCLEAR RADIATION. V. N. Borsoff, S. J. Beaubien and W. W. Kerlin. (Shell Oil Company, Shell Development Division, Emeryville, California, Contract AF 33(616)-6658, Final Report, 1 July 1959-30 June 1960, 170 p., 10 refs., WADD TR 60-424)

The work presented is an investigation of lubricating capabilities of unsubstituted polyphenyl ethers and a comparison of these ethers with conventional lubricants. The work consists of studying the performances of the lubricants in bearings and gears under severe thermal, oxidative and ionizing radiation stresses. Based on the evidence obtained, it appeared that all lubricants suffer an appreciable decrease in load carrying capacity at elevated temperatures, but preserve their lubricating properties under the most severe environments, providing the flow of oil to the load bearing elements is not impeded in any manner.

274. ENVIRONMENTAL CONSIDERATIONS FOR THERMAL PROTECTIVE COATINGS. R. M. VanVliet and J. J. Mattice. (U. S. Air Force, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, Technical Report 61-322, July 1961, pp. 436-455) also (Materials Symposium, Phoenix, Arizona, 13-15 September 1961) AD 264 193

275. THERMAL PROPERTIES OF MATERIALS AT ELEVATED TEMPERATURES. Herbert W. Deem, Webster D. Wood and Charles F. Lucks, Battelle Memorial Institute, Columbus, Ohio. (WADC Technical Note 59-215, Report on Materials Analysis and Evaluation Techniques, 1 July 1958-30 June 1959, December 1959, 22 p.)

Apparatus was designed and assembled for making linear-thermal-expansion, specific-heat, and thermal-conductivity measurements to 5000 F or above on metals and ceramic-type materials. Linear-thermal-expansion and specific-heat measurements are made in the same apparatus using the same specimen.

276. EFFECTS OF HIGH TEMPERATURE, HIGH VELOCITY GASES ON PLASTIC MATERIALS. Frank P. Baltakis, Donald E. Hurd and Roy F. Holmes, Convair, A Division of General Dynamics Corporation, San Diego, California. (U. S. Wright Air Development Division, Technical Report 59-459, June 1960, 34 p.) AD 243 368L

277. EVALUATION OF THE EFFECTS OF VERY LOW TEMPERATURES ON THE PROPERTIES OF AIRCRAFT AND MISSILE METALS. Leonard P. Rice, James E. Campbell and Ward F. Simmons. (U. S. Air Force, Wright Air Development Division, WADD Technical Report 60-254, June 1960, 61 p.) AD 243 623

Presents the tensile and hardness properties of eight different alloys of interest to the aircraft and missile industries at temperatures ranging from -253 C (liquid hydrogen) to room temperature. These alloys are Ti-6Al-4V, Ti-5Al-3Mo-1V, Ti-16V-2.5Al, and B-120VCA (all-beta alloy) titanium alloys; 17-7PH, PH15-7Mo, and Type 301XH stainless steels; and Vascojet 1000 alloy steel. In general, the values for hardness, elastic modulus, and tensile and yield strengths of these materials tended to increase as the test temperature was reduced to -253 C. However, of the eight alloys investigated, the Ti-6Al-4V and the Ti-4Al-3Mo-1V titanium alloys and the Type 301 XH stainless steel were the only ones that did not reveal a serious loss of ductility or did not fracture before reaching 0.2% offset strain at -253 C.

278. EFFECT OF INFRARED HEAT ON 45° TENSILE STRENGTH OF TWO REINFORCED PHENOLIC LAMINATES. Kenneth H. Boller. (U. S. Forest Products Laboratory, Report No. 1879, March 1961, 9 p.)

The study was conducted on tensile coupons from phenolic laminates made with either glass fabric or asbestos fibers and machined at 45° to the natural axes. The results of the first series, in which the temperature of the coupons was increased on the surface at a constant rate before loading, show the characteristic drop in strength with increases in temperature from air heating and a slightly greater drop in strength with infrared heating. The results of the second series in which the coupons were partially loaded and then heated with infrared on only one side at various rates from 1 to 29 F per second until failure occurred, showed that the hot-side temperature increased with increasing rate of temperature rise; furthermore the center temperature (average of hot and cold side) was relatively unaffected by rate of temperature rise. It therefore appears that thermal shock and subsequent thermal gradient did not produce small internal fractures in these phenolic coupons.

279. HIGH TEMPERATURE RADIATION RESISTANT MATERIALS. C. I. Carr and R. Miller. (United States Rubber Company, Wayne, New Jersey, Contract NObs-84025, Progress Report No. 3, 1 February-30 April 1961, 17 May 1961, 14 p.) AD-265 319

Stress relaxation studies for EPR containing $Sb_2O_3$ and Hypalon 40 have been carried out. A mixture of dialkyl hydrogen phosphite and a phenol antioxidant does not protect EPR against the effects of air oxidation. The adhesion of EPR to brass and steel wire is improved with this protective system. The addition of $Sb_2O_3$ and Hypalon to EPR does not alter its aging characteristics in ASTM No. 1, ASTM No. 3 oil and Tricresyl phosphate. Polyethylene and EPR with low levels of carbon black, containing $Sb_2O_3$ and a chlorinated paraffin exhibit good green and aged electrical properties.

280. EFFECTS OF HIGH VACUUM AND ULTRAVIOLET RADIATION ON NONMETALLIC MATERIALS. N. E. Wahl, R. R. Lapp and F. C. Haas, Cornell Aeronautical Laboratory, Inc., Buffalo, New York. (Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, WADD TR 60-125, Part II, April 1961)

The behavior of nonmetallic materials exposed to simulated space conditions of atmospheric composition, pressure, temperature, and ultraviolet radiation is investigated. A method of determining the absorptivity and heat-transfer characteristics of plastics exposed to vacuum ultraviolet is described.

281. SPACE--A NEW ENVIRONMENT FOR MATERIALS. W. H. Colner. (Materials Research and Standards, Vol 2, No. 7, August 1962, pp. 656-660)

Description of a Hughes Aircraft Company program for the investigation of the behavior of materials in the environment of space, with particular attention to the effects of high vacuum. The results of some environmental tests of various materials are presented.

282. FRICTION, WEAR, AND EVAPORATION RATES OF VARIOUS MATERIALS IN VACUUM TO $10^{-7}$ mm Hg. Donald H. Buckley, Max Swikert and Robert L. Johnson. (American Society of Lubrication Engineers, Preprint 61 LC-2, October 1961, 15 p.)

283. EFFECT OF HARD VACUUM AND LOW G CONDITIONS ON HYDRAULIC FLUIDS AND SYSTEMS. (Armed Services Technical Information Agency, Arlington, Virginia, Report Bibliography ARB-10656, Covering 1953 to 1962, June 1962, 12 p.)

284. EVAPORATION EFFECTS ON MATERIALS IN SPACE. Leonard D. Jaffe and John B. Rittenhouse. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Contract NASw-6, Technical Report No. 32-161, 30 October 1961, 18 p., 77 refs.)

Sublimation of inorganic materials in the vacuum of space can be predicted accurately from knowledge of their vapor pressures and, for compounds, of their free energies. Among the elements, cadmium, zinc, and selenium are readily lost near room temperature and magnesium at elevated temperatures. Selective loss at individual grains and at grain boundaries can produce some surface roughening. Evaporation rates of low-molecular-weight single-component oils can also be calculated from vapor pressures; most are rather high. Polymers lose weight in vacuum by decomposition; nylon, acrylics, polysulfides, and neoprene show high decomposition rates near room temperature. Many other polymers, including polyethylene and isoprene, are stable to high temperatures in vacuum. Engineering properties are, in general, little affected in vacuum unless appreciable loss of mass occurs.

285. SPACE VACUUM POSES DESIGN PROBLEMS. L. D. Jaffe. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Technical Release 34-209) also (Nucleonics, Vol. 19, No. 4, April 1961)

The extreme space vacuum presents two major problems to designers of space-vehicle hardware: (1) The surfaces of materials exposed to the vacuum can sublimate or evaporate, especially at high temperatures. To counteract this effect designers must choose materials with low vapor pressure. (2) Surfaces in frictional contact tend to weld together when exposed to the very low vacuums of space. These surfaces must be lubricated with a material that prevents welding, but will not itself evaporate into vacuum.

286. HIGH-VACUUM, HIGH-TEMPERATURE, SOLID LUBRICANT (TVERDAYA VYSOKOVAKUUMNAYA VYSOKOTEMPERATURNAYA SMAZKA). L. N. Sentyurikhina, B. N. Malyshev and others. (Khimiya i Tekhnologiya Topliv i Masel, Vol. 7, 1961, pp. 13-15) also (Air Force Systems Command, Foreigh Technical Division, Wright-Patterson Air Force Base, Ohio, Translation No. FTD-TT-61-58, 4 October 1961, 6 p.) AD-265 806

287. ULTRAVIOLET AND VACUUM EFFECTS ON INORGANIC MATERIALS. AN ANNOTATED BIBLIOGRAPHY. Robert C. Gex. (Lockheed Aircraft Corporation, Sunnyvale, California, Special Bibliography No. SB-61-19, April 1961, 33 p., 73 refs.) AD-258 092

A selected list of 73 annotated references are presented on the effects of the vacuum and ultraviolet on inorganic materials. Primarily the effects reported in the literature are on the optical properties of inorganic films. Emphasis was placed on recent literature, from 1958 on. The references are arranged alphabetically by author; an index by material is also provided. Sources used were Physics Abstracts, Chemical Abstracts, Ceramics Abstracts, Engineering Index, Nuclear Science Abstracts, ASTIA, and LMSD card catalog.

288. MATERIALS EVALUATION UNDER HIGH VACUUM AND OTHER SATELLITE ENVIRONMENTAL CONDITIONS. P. H. Blackmon, F. J. Clauss, G. E. Ledger and R. E. Mauri. (Lockheed Aircraft Corporation, Missiles and Space Division, Sunnyvale, California, Report TR 3-77-61-23, January 1962)

Lubricants and bearings, paints and other temperature control surfaces, bulk plastics and polymer films, and adhesives are being tested for satellite applications under vacuum and radiation conditions. Test equipment and data are discussed.

289. EFFECT OF VACUUM ENVIRONMENT ON THE MECHANICAL BEHAVIOR OF MATERIALS., I. R. Kramer and S. E. Podlaseck. (Martin Company, Baltimore, Maryland, Contract AF 49(638)-946, Report No. RM-102, Final Report, 1 October 1960-1 October 1961, October 1961, 46 p., AFOSR-2139) AD-273 250

Apparatus for conducting fatigue, tensile and creep studies in the pressure range 760 mm to 10 to the -8th power mm Hg is described. Experimental data are presented for Al single crystals showing, with decreasing pressure, an improvement in fatigue life and a decrease of strength in tension and creep.

290. BEARINGS FOR VACUUM OPERATION RETAINER MATERIAL AND DESIGN. Harold E. Evans and Thomas W. Flatley. (National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, Technical Note D-1339, May 1962, 17 p.)

This report describes the initial phase of an investigation of the high-speed operation of miniature ball bearings, with metallic film lubrication, in a vacuum environment. Phase I of this study, was conducted to determine the most promising retainer material and design for use in a general study of the effectiveness of various metallic coatings as lubricants. Fully machined retainers of five different materials, with all balls and races of gold-plated 440C stainless steel, were tested. Both pure gold plating and gold with additives were investigated. Size R2-5 bearings were run without external loading at a nominal motor speed of 10,000 rpm and the goal is a bearing life of 1,000 hours in an ambient pressure of $10^{-7}$ torr. The results show that: (1) Thin metallic films as lubricants show real promise when used in a vacuum environment; (2) pure gold plating is not as effective as the plating with additives; (3) fully machined retainers provide good performance, and the use of relatively hard retainer materials significantly extends the useful life of the bearings; and (4) the bearing failures tended to be catastrophic rather than gradual, making the prediction of the onset of failure difficult.

291. INVESTIGATION OF ADHESION AND COHESION OF METALS IN ULTRAHIGH VACUUM. John L. Ham. (National Research Corporation, NASA Contract NASr-48, First Quarterly Progress Report, Period 15 June-15 September 1961, 8 p.)

The original apparatus and tabular data on preliminary attempts to join specimens of copper were presented in the proposal. It was designed to make and break or break and make hot cylindrical specimens end to end. Force is applied by heating or cooling the legs of the yoke; heat is provided by electron bombardment; and force measured by electrical transducers.

292. INVESTIGATION OF ADHESION AND COHESION OF METALS IN ULTRAHIGH VACUUM. John L. Ham. (National Research Corporation, NASA Contract NASr-48, Second Quarterly Progress Report, Period 15 September-15 December 1961, 11 p.)

This report presents data obtained by breaking and making a sample of copper 49 times at various temperatures and a sample of 1018 steel 10 times at 500°C and various pressures. Time in contact and time apart were also varied.

293. BEARINGS FOR VACUUM OPERATION--PHASE I. Harold E. Evans and Thomas W. Flatley, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland. (National Symposium on The Effects of Space Environment on Materials, St. Louis, Missouri, 7-9 May 1962, 30 p., 4 refs.)

This report describes the initial phase of an investigation of the high speed operation of miniature ball bearings, with metallic film lubrication, in a vacuum environment.

294. EFFECTS OF HIGH VACUUM AND RADIATION ON POLYMERIC MATERIALS. Norman E. Wahl and John V. Robinson, Bell Aerosystems Company. (National Symposium on The Effects of Space Environment on Materials, St. Louis, Missouri, 7-9 May 1962, 28 p., 6 refs.)

This paper describes experimental studies that were conducted to determine the effects of heat, low pressure and radiation on plastics and elastomeric materials.

295. VACUUM STUDIES GIVE ANSWERS ON MATERIALS FOR SPACE. W.B. Wallace. (Product Engineering, Vol. 33, No. 3, 5 February 1962, pp. 74-75)

Ultra-high vacuum testing techniques are described briefly. Results are given for some of these tests in the areas of lubrication, cold welding, plastic coating, and exposure of microorganisms.

SECTION D

**Vacuum**

296. STUDY OF THE EFFECTS OF ENVIRONMENTAL CONDITIONS ON THE BREAKDOWN OF ANTENNAS AT LOW PRESSURES ON A SUPERSONIC VEHICLE. J. B. Chown and M. G. Keenan. (Stanford Research Institute, Menlo Park, California, Contract AF 19(604)-5483, Final Report, September 1961, 64 p., 15 refs., AFCRL-940) AD 267 163

The breakdown characteristics of antennas under supersonic flight conditions at altitudes up to 80 miles were investigated. Three Nike-Cajun rockets were instrumented and fired from Eglin Gulf Test Range on 4 November 1960 and on 14 and 24 March 1961. Significant results were obtained only from the 14 March firing. Details of the instrumentation and data obtained are given. Data are given on the RF power required to initiate and extinguish breakdown, surface temperatures, and pressure on the surface of the conical nose. A comparison of breakdown data with previously obtained laboratory data and with the theory of breakdown phenomena reveals discrepancies which remain unresolved due to the limited quantity of flight data available.

297. MOLECULAR APPROACH TO DRY FILM LUBRICATION IN A VACUUM (SPACE) ENVIRONMENT. R. M. Van Vliet. (U. S. Air Force, Wright Air Development Division, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, Projects 3044 and 7312, WADC Technical Report 59-127, July 1960, 35 p., 17 refs.)

This report presents an analysis of the problems associated with the use of dry film lubricants at moderate temperatures on unpressurized space vehicles. The effects and suspected effects of vacuum on dry film lubricants are analyzed in detail to provide the basis for future research programs in this area. Several hypotheses for lubricant-environment interaction are presented and a few basic research approaches are suggested.

298. ELECTRICAL BREAKDOWN IN VACUUM. R. P. Little, S. T. Smith and H. D. Arnett. (U. S. Navy, Naval Research Laboratory, Washington, D. C., Project No. RF 009-01-41-6064, NRL Report No. 5671, Interim Report, 2 October 1961, 19 p.) AD-266 603

The voltage breakdown in vacuum was studied at gap spacings of 0.015 inch. Measurements indicate little or no variation of breakdown with tube pressure between approximately 10 to the -5th and 10 to the -7th power torr and with frequency of the applied voltage from 0 to 6 Mc. Electrical breakdown in vacuum is prefaced by prebreakdown currents caused by electron emission from small isolated areas on the cathode electrode. As a result of this emission, individual, small-diameter electron beams are formed between cathode and anode. These beams can cause the anode and cathode power dissipation density to become extremely high, resulting in evaporation, melting, and destructive effects. The observed prebreakdown emission is believed to result from contaminants modifying the image barrier of the cathode and not from local field enhancements due to irregularities of the cathode surface.

299. EFFECTS OF ULTRAVIOLET AND VACUUM ON PROPERTIES OF PLASTICS. Norman F. Wahl. (U. S. Wright Air Development Division, Technical Report 60-101) also (Conference on Behavior of Plastics in Advanced Flight Vehicle Environments, H. S. Schwartz, September 1960, pp. 445-455)

The effects of low pressure and ultraviolet radiation on the weight and strength of glass reinforced polyester, epoxy and phenolic laminates were determined after exposure periods of 24, 50, 100, 200, and 500 hr. The ultraviolet spectrum ranged from 2000 to 6000 A with an incident radiant flux of 2 cal/sq cm/min. Pressures were of the order of $10^{-7}$ mm of mercury with ambient temperatures up to 300 F.

These preliminary tests indicated that exposures to the combined environments for 500 hr had no marked effect on weight loss and flexural strength of any of the laminates. Weight losses were approximately 1%. The polyester laminate showed a significant increase in flexural strength up to 200 hr. This was attributed to further cross-linking. After 500 hr, however, strength decreased to a level slightly greater than the original strength. The epoxy and phenolic laminates lost approximately 10% of their original strength after 500 hr.

300. PRESENT-DAY IDEAS CONCERNING THE MECHANISM OF ELECTRICAL BREAKDOWN IN HIGH VACUUM. L. V. Tarasova. (Uspekhi Fizicheskikh Nauk, Vol. 58, No. 2, February 1956, pp. 321-346) also (U. S. National Aeronautics and Space Administration, Technical Translation F-42, October 1960, 35 p.)

# SECTION E

## General

301. INVESTIGATE THE EFFECT OF HIGH DYNAMIC PRESSURES UPON THE METALLURGICAL PROPERTIES OF IRON AND TITANIUM BASE ALLOYS. (Aerojet-General Corporation, Downey, California, Contract AF 33(616)-8191, Report No. 0485-01(01)QP, Quarterly Progress Report No. 1, 15 April-15 July 1961, 24 July 1961, 1 vol.) AD-267 065

The effects of high dynamic pressures on the metallurgical properties of AISI 1020 steel specimens are demonstrated by an appreciable increase in surface hardness and metallurgical changes in grain structure. High density deformation twins are shown as a result of the dynamic pressures. A chevron patter with alternating bands of high and low deformation twins is observed.

302. COATINGS FOR THE AEROSPACE ENVIRONMENT. Robert M. Van Vliet, (Aeronautical Systems Division, Directorate of Materials and Processes, Wright-Patterson Air Force Base, Ohio, Project 7312, Report on Finishes and Materials Preservation, July 1961, 360 p., 58 refs., WADD TR 60-773) AD-267 310

Contents: Spacial distribution of UV light; Design of organic coatings for use in space; Protective UV absorbers in space; Evaluation of polymeric materials for space use; UV effects on high polymers and relation to radiation chemistry; Simulated solar irradiation and photo-chemical effects on plastic spacecraft materials; Decomposition of organic resins at high temperature in a vacuum; Materials effects in spacecraft thermal control; Reflective metal coatings; Power systems for astronautical applications; Selective coatings for extraterrestrial solar energy conversion, analysis; Use of optical interference to obtain selective energy absorption; High-temperature surface parameters for solar power; Low emissivity coatings for use at high temperatures; Ceramic coatings for control of reflectivity and emissivity of Inconel; Anodic coating for temperature control in space vehicles; Coatings for unfurlable reentry vehicle; Surface treatment of filters to improve dielectric coatings; Thermal stability of slightly soluble inhibitive salts and their properties.

303. HANDBOOK OF DESIGN DATA ON ELASTOMERIC MATERIALS USED IN AEROSPACE SYSTEMS. (Aeronautical Systems Division, ASD-TR-61-234, January 1962, 222 p.) AD 273 880

The objective of this handbook is to provide aerospace weapons systems design engineers with useful data on the materials properties of elastomers. The sources of this information are Department of Defense research reports and the technical literature of engineering design and elastomer technology. The elastomeric materials for which data are presented are compounds of high polymers currently available in the U.S.A. The properties considered are original mechanical and physical properties and the changes in these properties that result from aging and exposure to environments of aerospace weapon systems. A selected bibliography of technical literature on elastomers and elastomeric parts is included to aid the handbook user who needs further information on these topics.

304. SURFACE EFFECTS ON MATERIALS IN NEAR SPACE. Francis J. Clauss. (Aero/Space Engineering, Vol. 19, October 1960, pp. 16-19)

305. EFFECTIVENESS OF RADIATION AS A STRUCTURAL COOLING TECHNIQUE FOR HYPERSONIC VEHICLES. Roger A. Anderson and William A Brooks, Jr. (Aero/Space Sciences, Journal, Vol. 27, January 1960, pp. 41-48)

An analysis is made of the more significant effects of internal heat transfer within idealized structures, both with and without external insulation on areas of greatest aerodynamic heating intensity. Selective use of insulation leads to structural temperature reductions substantially greater than those obtained without insulation.

306. ENVIRONMENTAL FACTORS INFLUENCING METALS APPLICATIONS IN SPACE VEHICLES. J. M. Allen. (Battelle Memorial Institute, Defense Metals Information Center, Columbus, Ohio, DMIC Report 142, 1 December 1960, 46 p., 34 refs.)

Metals will be used extensively both in the vehicle structure and in the supporting and auxiliary equipment that is used for space flight. This report describes the specialized environments which are imposed on metals and the possible consequences of these environments. In general, the specialized environments are identified with (1) the natural environment of space, (2) the entry into an atmosphere, or (3) the power-conversion system utilized by the vehicle.

307. BEHAVIOR OF MATERIALS IN SPACE ENVIRONMENTS. L. D. Jaffe and J. B. Rittenhouse. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Contract NASw-6, Technical Report No. 32-150, 1 November 1961, 116 p., 330 refs.) AD-266 548

Quantitative effects of space environments upon engineering materials are discussed. Most metals will be unaffected by vacuum except for slight surface roughening. Among organics, polysulfides, cellulosics, acrylics, polyvinyl chloride, neoprene, and some nylons, polyesters, epoxys, polyurethanes, and alkyds break down at low temperatures in vacuum. Polyethylene, polypropylene, most fluorocarbons, and silicone resins do not decompose significantly in vacuum below 250 C. Except for plasticized materials, significant loss of engineering properties in vacuum is unlikely without appreciable accompanying sublimation or decomposition. Certain low vapor pressure oils and greases, tetrafluorethylene, and thin films of $MoS_2$, Au, and Ag can probably provide adequate lubrication. The particles of the Earth's radiation belts will cause radiation damage to organics and optical properties of inorganic insulators. Semiconductors affected by solar flare emissions.

308. EFFECTS OF SPACE ENVIRONMENT UPON PLASTICS AND ELASTOMERS. L. D. Jaffe. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Contract NASw-6, Technical Report No. 32-176, 16 November 1961, 22 p., 147 refs.) AD-268 432

Most polymers will be stable in the vacuum of space at temperatures as high as they can withstand in air. Important exceptions are some nylons, polysulfides, cellulosics, acrylics, polyesters, epoxies, and urethanes. Exposure to vacuum will not cause loss of engineering properties unless appreciable loss in weight occurs. Through a shielding thickness of 1 g/cc, only the more radiation-sensitive polymers will be damaged by the Van Allen belts, and solar flare emissions will cause no permanent damage. Sunlight of 100-1000 angstrons wavelength may significantly increase optical absorption by the outer few thousand angstroms of an exposed surface. Longer solar wavelengths induce cross-linking to much greater depths, reducing elastomer flexibility and increasing optical absorption. Most other engineering properties are likely to be less affected by sunlight in space than on the Earth's surface.

309. ENVIRONMENTAL DESIGN OF SPACECRAFT. Marcus G. Comuntzis. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Contract NASw-6, Technical Release No. 34-31, 3 May 1960, 9 p.) AD-235 333

Environmental design philosophies and the importance of environmental testing in the design of spacecraft are discussed, with a detailed discussion of the actual environmental testing of one of the mechanisms of Pioneer IV.

310. MATERIALS IN SPACE. Ralph A. Happe. (California Institute of Technology, Jet Propulsion Laboratory, Pasadena, Contract NASw-6, Technical Release No. 34-143, 18 October 1960, 17 p.) also (Paper presented to American Ordnance Association, Cleveland, Ohio, 21 October 1960) AD-244 492

Contents (A lecture) include: The space environment; Materials use on the Ranger; Effect of the space environment on inorganic materials; Effect of the space environment on organic materials.

311. SPACE ENVIRONMENT. Marcia Neugebauer. (California Institute of Technology, Jet Propulsion Laboratory, Contract NASw-6, Technical Release No. 34-229, December 1960, 15 p.) AD 250 885

The space environment is described in this Report by means of a listing of one or more key references for each type of radiation or particles found in space. This is not intended as a complete bibliography. Wherever possible, review articles have been chosen, that is; articles which give the reader the broad outlines of the subject and then list references for more detailed study.

312. DESIGN CRITERIA FOR SPACE RECORDERS. M. A. Wells. (CEC/Recordings, Vol. 16, 1st Quarter, 1962, pp. 4-8)

Discussion of the factors involved in the design of tape recorders for space vehicles, covering (1) size; (2) data-storage requirements; (3) electromechanical techniques; (4) electronic and magnetic requirements; and (5) environmental conditions. Illustration is made by reference to recorders developed by Consolidated Electrodynamics Corporation.

313. ELECTRONIC MATERIALS AND COMPONENTS FOR EXTREME ENVIRONMENTAL PROBLEMS. Alex E. Javitz and Paul G. Jacobs. (Electrical Manufacturing, Staff-Research Report, Vol. 62, No. 5, November 1958 pp.111-134, 49 refs.)

This review will endeavor to being into focus the problem areas and current state of the art of electronic materials and component parts required to sustain reliable operation under the extraordinary environments encountered by nuclear and supersonic military equipments. Ultrahigh temperature ambients (500 C and higher) and nuclear radiation effects (in combination or separately) are the primary considerations. Acoustical noise, extreme vibration, and the effects of ozone are other critical environments. Elevated temperatures in conjunction with gamma and neutron radiation become a problem also in the design of nonmilitary nuclear reactor instrumentation.

314. MATERIALS FOR ENVIRONMENTAL EXTREMES. I. TOMORROW'S ENVIRONMENTAL EXTREMES. II. ENVIRONMENTAL LIMITS OF MATERIALS. III. COMPATABILITY OF MATERIALS. IV. MATERIALS DEVELOPMENT NEEDS. George Sideris. (Electronics, Vol. 32, No. 49, 4 December 1959, pp. 81-96)

Use of electronic equipment in high-speed aircraft, space vehicles and nuclear environments is bringing about serious problems of heat, radiation, and stress. Research is raising endurance limits of materials like structural metals, conductors and magnetic materials; components such as transducers, semiconductor devices, capacitors, resistors. A system approach to guide you in selection of contacting metals, plating processes, protective coatings, and insulating materials is given. What is being done to improve materials for extreme environments? Measures include: seeking high purity in materials, environmental testing of complete systems and uniform standards.

315. AEROSPACE ELECTRONIC MATERIALS--APPLICATION/ENVIRONMENTS/EFFECTS. E. G. Linden. (Electro-Technology, Vol. 68, No. 6, December 1961, pp. 125-131)

316. ELECTRONIC PACKAGES VS. SPACE TORTURE. Arnold Pollack, Aerotest Laboratories, Inc. (Environmental Quarterly, Vol. 7, No. 4, October 1961, pp. 20-23)

Electronic packages can survive in space when the designer keeps thermal effects in mind and checks his design by subjecting it to simulated space tests. While thermal design positions packages and brackets, and selects materials and coatings, thermal vacuum tests in space chambers prove out the design and locate trouble spots.

317. ANALYSIS OF HYPER ENVIRONMENTS AND THEIR RELATION TO MILITARY HARDWARE IN THE INTERIOR OF A SPACE VEHICLE. M. H. Simpson. (Frankford Arsenal, Pitman-Dunn Laboratories Group, Philadelphia, Project No. TS1-15, Technical Memo. No. M60-21-1, February 1960, 17 p.) AD-244 826

Discussion of the natural environments of space (above 75,000 ft) as they effect the design and testing of military components, subassemblies, and sub-systems within the interior of a space vehicle; analytical determinations of the factors of mass heat transfer of conduction, convection, and radiation; the factors of low absolute pressures, ozone, radiation, ionization, and meteoritic dust; and the relation in effects for the designer. The discussion is not a cut and dried recipe, but a guide for assessing the variables involved relative to the hardware within a vehicle.

318. BASIC INVESTIGATION OF THE OPERATION OF PROPELLANT ACTUATED DEVICES IN SPACE ENVIRONMENT. PHASE I, A LITERATURE SURVEY. Gilbert H. Skopp. (Frankford Arsenal, Pitmann-Dunn Laboratories Group, Philadelphia, Report No. R-1545, November 1960, 46 p., WADD TR 60-346) AD-255 204

Phase I of this program entails a compilation of the environments and a bibliography pertaining to the environments of space operations. The weapon systems subjected to the hyperenvironments are classified into short duration (1 to 2 hr) flying-type and ballistic-type vehicles operating from a 75,000 to 300,000 ft altitude range, and into long-duration satellite vehicles orbiting around the earth in the 200- to 400-mi altitude range. Sustained flight, boost glide, ballistic, and satellite vehicles are included in these considerations. The natural environmental conditions considered are categorized under, atmospheric composition, extreme high vacuum, solar radiation, ozone, dissociated gases, aurorae, ionized gases, solid particles, magnetic field, cosmic radiation, and low temperature. The induced environments are categorized under high temperature, acceleration, vibration, acoustical excitation shock, zero gravity, and nuclear irradiation.

319. SOLAR-FLARE EFFECTS ON 2.5 AND 5.0 MC/S ATMOSPHERIC RADIO NOISE. J. R. Herman. (Geophysical Research, Journal, Vol. 66, No. 10, October 1961, pp. 3163-3167)

320. SPACE ENVIRONMENTS AND THE RELIABILITY OF HYDRAULIC CONTROLS. A. B. Billet, Vickers, Inc., Detroit, Michigan. (IAS System Reliability Symposium, Proceedings, Salt Lake City, Utah, 16-18 April 1962, p. 111)

Special consideration is given to furthering the development and increasing the reliability of hydraulic control for space vehicles. High temperature, shock, low ambient pressure, ozone, radiation, cosmic rays, dissociation, and other environmental conditions are discussed.

321. EFFECT OF ENVIRONMENT ON THE BEHAVIOR OF MATERIALS. I. R. Kramer and S. E. Podlaseck. (Institute of Aerospace Sciences, Summer Meeting, Los Angeles, California, 19-22 August 1962, Paper 62-104, 19 p., 40 refs.)

USAF-NASA-supported discussion of the effects of space environment on the mechanical and physical properties of metals and organic materials. Some results of earlier investigations of surface effects on metals are reviewed, as are the mechanisms proposed for the effects of oxide and metal films and the influence of electrolytes. Particular attention is directed to the effects of surface removal of metals during plastic deformation, and the effects of low vacuum radiation, and erosion by meteoric particles on organic materials.

322. PROBLEMS ASSOCIATED WITH RANDOM VIBRATION TESTS OF ROCKET-BORNE ITEMS. Austin L. Howard and Wayne M. Traylor, U. S. Naval Research Laboratory, Washington, D. C. (Institute of Environmental Sciences Annual Technical Meeting, 1959 Proceedings, Chicago, 22-24 April 1959, pp. 50-56)

323. PACKAGING ELECTRONIC EQUIPMENT FOR THE VIBRATION ENVIRONMENT. Richard A. Hirsch, Aircraft Armaments, Inc. (Institute of Environmental Sciences Annual Technical Meeting, 1959 Proceedings, Chicago, 22-24 April 1959, pp. 11-14)

This paper is concerned primarily with the structural design of the equipment package and as such is concerned with shock and vibration.

The mechanical and structural aspects of designing military electronic equipment are generally a small percentage of the total engineering effort required. This is, of course, as it should be, and in fact these aspects should be reduced to more or less routine procedures. In order to achieve this general objective it has been the philosophy to compute stiffness factors by elementary means and apply correction factors to account for the shortcomings of the simplified analysis. The purpose of the test program undertaken is to measure stiffness factors under dynamic conditions and thus generate the required correction factors.

324. FAILURE OF ELECTRONICS IN HIGH INTENSITY SOUND FIELDS.
George W. Kamperman, Norman Doelling, Bolt Beranek and Newman, Inc., Cambridge, Massachusetts. (Institute of Environmental Sciences Annual Technical Meeting, 1959 Proceedings, Chicago, 22-24 April 1959, pp. 262-265)

The designer of electronic equipment is faced with many environmental variables that may modify the performance of equipment. Among these variables are temperature, humidity, pressure, radiation, and vibration. More recently sound has become of interest also. Although many physical mechanisms are involved in the failure of electronic equipment in high intensity sound fields, most of the so-called sonic failures are caused by excitation of vibration fields by the surrounding sound field. This paper is concerned with some of the relations between sound fields and the resulting vibration fields. Some preliminary experiments are presented here to illustrate the nature of the transfer of sound energy to vibration energy. In addition, research programs designed to study this transfer and other aspects of sound-induced or sonic fatigue are outlined.

325. MAGNETIC CORES AND PERMANENT MAGNETS IN HYPER-ENVIRONMENTS.
D. I. Gordon. (Institute of Environmental Science, Proceedings, Los Angeles, 6-8 April 1960)

326. SPACE ENVIRONMENT AND ITS EFFECTS ON MATERIALS AND COMPONENT PARTS.
S. N. Lehr and V. J. Tronolone. (IRE Transactions of Reliability and Quality Control, Vol. RQC-10, No. 2, August 1961, pp. 24-37, 56 refs.)

The best available preliminary information has been gathered on materials which can be used successfully and how they react in various space environments. In addition to the factors presented, such items must be considered as: the exact nature of the missile of a space vehicle, the type of orbit, the length of time the vehicle is expected to function, the reliability objective, and similar goals, although regárdless of the mission, certain general effects of the space environment present problems which must be met in the design itself. Data have been gathered on these general effects, which include high vacuum, magnetic fields, gravitational fields, micro-meteorites, cosmic rays, neutrons, trapped charged particles, and electromagnetic radiation, including ultraviolet light, X-rays, and gamma rays.

327. SOME ASPECTS OF SATELLITE AND SPACE PROBE RELIABILITY. T. W. Gross and H. C. Werner. (IRE Transactions on Reliability and Quality Control, Vol. RQC-10, No. 3, November 1961, pp. 7-14)

It is becoming a recognized fact that many of the electronic piece parts used in present day ballistic missile and space probes are inadequate for the long-life space programmes of the near future. Realization of the major differences of life and reliability requirements resulting from short and long term exposures to the space environment has led to a four point plan for the establishment of an acceptable class of parts that will meet the more rigid demands. Presented here are the plan and some of the preliminary results obtained to date.

328. PRELIMINARY ENVIRONMENTAL CONSIDERATIONS EFFECTING THE PERFORMANCE OF LARGE OPTICS FOR AEROSPACE RECONNAISSANCE. R. Joel. (Itek Laboratories, Lexington, Massachusetts, Technical Note No. 2, Report IL 9026-5, October 1961, 63 p.)

329. DIELECTRICS FOR OUTER SPACE. Louis J. Frisco. (Johns Hopkins University, Dielectrics Laboratory, Baltimore, Maryland, Contract DA 36-039-sc-78321, Interim Report No. 1, 1 March 1959-30 April 1960, 31 May 1960, 65 p., 16 refs.) AD-240 028

The results of the first phase of a study of the effects of simulated high altitude environment on the electrical properties of electrical insulating materials are reported. Tests have been made for periods up to 96-hours in high vacuum, in the presence of ultraviolet and 50-kv X-ray radiation. Measurements of flashover strength from 60-cps to 18-mc, dielectric constant and dissipation factor from 60-cps to 100-mc, and d-c surface and volume resistivity have been made on Alathon 4 BM 30, Alox (aluminum oxide) glass polyester laminate, and Formica FF-95 printed wiring board. Observed changes in electrical properties are associated mainly with thermal effects, except in the case of flashover. Electrode effects prove to be important in high vacuum flashover phenomena, causing minimum values in high vacuum to be comparable to the low values obtained at atmospheric pressure.

330. DIELECTRICS FOR SATELLITES AND SPACE VEHICLES. Louis J. Frisco. (Dielectrics Laboratory, John Hopkins University. Baltimore, Maryland, Contract DA 36-039-sc-78321, Report No. 2, 1 May 1960-28 February 1961, 15 March 1961. 79 p., 17 refs.) AD-256 900

Results of the second phases of study of the effects of simulated high altitude environment of the electrical properties of insulating materials are reported. High vacuum breakdown and flashover measurements in the 10 to the -6th power mmHg range at d-c, 60-cps, 2-mc and 18-mc indicate that electrode surface roughness is the controlling factor. Dielectric properties of the specimen material do not influence flashover voltage. X-ray and ultraviolet radiation have no effect of flashover voltage. Significant changes in low-frequency loss properties and d-c conductivity were observed during and after vacuum irradiation with 50-KV x-rays. Ultraviolet radiation produced no immediate effects on loss properties.

331. ELECTRICAL CONTACTS IN SPACE ENVIRONMENT. AN ANNOTATED BIBLIOGRAPHY. George E. Owens. (Lockheed Aircraft Corporation, Sunnyvale, California, Report No. 3-77-61-1, Special Bibliography No. SB-61-23, May 1961, 84 p., 169 refs.) AD-258 424

A bibliography is presented which is the result of a survey of recent literature pertaining to electrical contacts in a space environment. It supports a laboratory investigation into the effects of strong ultraviolet radiation, hard vacuum (10 to the -8th power mm Hg or less), and low temperature (-50 to +200F) upon moving electrical contacts operating at currents in the milliampere-microampere range and at contact potentials up to a few millivolts. The bibliography includes references to work antecedent to the laboratory investigation, even though such work may not have been carried out within the specified range of conditions. The 169 references are arranged alphabetically by personal authors in 3 categories: (1) books, (2) reports, and (3) journal articles. An index of secondary personal authors and corporate sources is provided, in addition to a subject index.

332. SPACE ENVIRONMENTAL EFFECTS ON SEALS, GASKETS, ADHESIVES AND OTHER ELASTOMERIC AND POLYMERIC MATERIALS: AN ANNOTATED BIBLIOGRAPHY. Helen M. Abbott. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 04(647)-673, Report No. 3-34-61-7, Special Bibliography SB-61-40, September 1961, 218 p.) AD-267 531

This bibliography contains selected references on seals, gaskets, adhesives, sealants and other elastomeric and polymeric materials under space conditions. Environmental conditions that will effect materials in space are exposure to high vacuum, service temperatures, and radiation. Radiation includes ultraviolet and high-energy radiation as appropriate to the application of the material. Any application of adhesives in fabricating pressurized containers and attaching solar cell plates were included as were any tests conducted on materials used for seals and gaskets in contact with reactive fluids such as, hydrazine, UDMH (unsymmetrical dimethyl hydrazine), N2O4 and red fuming nitric acid. Materials used for inflatable space vehicles and structures are included as general applications of plastics or polymers.

333. SPACE ENVIRONMENTAL EFFECTS ON GEARS AND BEARINGS. AN ANNOTATED BIBLIOGRAPHY. Helen M. Abbott. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 04(647)-673, Addendum to the Space Materials Handbook, Report No. 3-34-61-12, Special Bibliography No. SB-61-49, October 1961, 72 p.) AD-269 556

An annotated bibliography on gears and bearings, resulting from a general literature search as an aid to the consideration of design factors, temperature, speed effects and wear problems on materials that could give satisfactory service in spacecraft applications is presented.

334. III RELIABILITY TESTING OF CAPACITORS IN COMBINED ENVIRONMENTS. S. G. Pryor. (Lockheed Aircraft Corporation, Nuclear Products, Georgia Division, Marietta, Contract AF 33(600)-38947, Report NR-116, 1 April-30 September 1960, December 1960)

335. STUDY AND DESIGN OF UNFURLABLE ANTENNAS. VOLUME II. ENVIRONMENT AND PROPAGATION STUDY. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 33(616)-6022, LMSD-48346, Vol. 2, Quarterly engineering report number 1, 1 August 1958-31 October 1958, 30 November 1958) AD-207 004 (see also) AD-313 829

The most recent available information is presented on space environmental factors, as they can affect the design of unfurlable antennas. Effects of atmospheric drag on satellite lifetime are discussed as a function of the unfurled antenna area, along with the effects of high vacuum, temperature, and such atmospheric constituents as dissociated gases and solid particles.

336. STUDY AND DESIGN OF UNFURLABLE ANTENNAS. VOLUME II. SPACE ENVIRONMENT AND ITS EFFECTS. (Lockheed Aircraft Corporation, Sunnyvale, California, Contract AF 33(616)-6022, LMSD-48448, Vol. 2, Quarterly Engineering Report No. 2, 1 November 1958-31 January 1959, 28 February 1959) AD 211 877 (see also) AD 207 004

Discussions are included on the effects of external torques caused by aerodynamic drag, radiation pressure, and gravitational and centrifugal forces, as well as those from electric and magnetic fields. Recent data on radiation levels in space as monitored by the lunar probes are discussed. A basic design approach to an unfurled antenna is outlined in that light of what is known of the overall space environment, and brief reference is made to continuing propagation studies. An extensive study of radiation damage to commonly used antenna materials is presented.

337. LUBRICANTS AND SELF-LUBRICATING MATERIALS FOR SPACECRAFT MECHANISMS. F. J. Clauss. (Lockheed Aircraft Corporation, Sunnyvale, California, Report No. LMSD-894812, 18 April 1961, 147 p., 97 refs.)

Little information exists on either the implications of space environment for the lubrication problem or the behavior of lubricants and self-lubricating materials under such conditions. This report discusses problems anticipated in providing satisfactory lubrication for space craft mechanisms and summarizes available information on the applicability of various lubricants and self-lubricating materials to solve such problems. The materials discussed are oils and greases, laminar solids, soft metals, plastics, and ceramics and cermets.

338. SATELLITE ENVIRONMENT HANDBOOK. F. S. Johnson, Editor. (Lockheed Aircraft Corporation, Missiles and Space Division, Sunnyvale, California, LMSD-895006, December 1960)

A rather comprehensive review of the readily available data which describe the geophysical environment ecountered by artificial Earth satellites is presented. The material is divided into the following sections: "The Physical Properties of the Upper Atmosphere," by F. S. Johnson; "Ionospheric Structure," by W. B. Hanson; "Penetrating Radiation," by A. J. Dessler; "Solar Radiation," by F. S. Johnson; "Micrometeorites," by J. Veddar; "Radio Noise," by O. K. Garriott; "Distribution of Thermal Radiation From the Earth," by F. S. Johnson; and "Geomagnetism," by A. J. Dessler.

339. EVALUATING THE BEHAVIOR OF MATERIALS UNDER SPACE CONDITIONS. F. J. Clauss, R. E. Mauri, E. C. Smith and S. Drake, Lockheed Aircraft Corporation, Missiles and Space Division, Palo Alto, California. (Institute of Environmental Sciences Proceedings, April 1961, pp. 475-488)

340. BEHAVIOR OF FLUIDS AND LUBRICANTS UNDER EXTREME ENVIRONMENTS. Vern Hopkins. (Midwest Research Institute, Kansas City, Missouri, Contract AF 33(616)-6854, Quarterly Progress Report No. 4 on Phase 1, 1 January-1 April 1961, 1 April 1961, 29 p.) AD-256 760

Results of 2 shear stability experiments at 400 F are presented. The run with MLO 59-91 (di-a-dodecyldiphenylsilane with additives) was terminated at 10.5 hr. when some of the mating pump parts were scuffed. The run with MLO 60-294 (deep dewaxed mineral oil plus TCP, PANA, and DC 200) complete the scheduled 50 hr. Both the fluid and pump were in good shape at the conclusion of this run. Wear-life results for a group of experimental solid film lubricants applied to spherical mating surfaces of bearings are presented for 400 F and 700 F, 1200-lb. radial load, while under a +14 to -14 degree oscillatory motion at 250 cpm. Seizure load results run at elevated temperatures for MLO 58-678 and MLO 58-678 with additives in an air atmosphere indicate the base fluid has better extreme pressure lubricating characteristics than with the various additives.

341. BEHAVIOR OF FLUIDS AND LUBRICANTS UNDER EXTREME ENVIRONMENTS. Vern Hopkins, A. D. St. John and D. R. Wilson. (Midwest Research Institute, Kansas City, Missouri, Contract AF 33(616)-6854, Quarterly Progress Report No. 6, 1 July-1 October 1961, 20 October 1961, 32 p.) AD-265 876

342. BEHAVIOR OF PLASTICS IN RE-ENTRY ENVIRONMENTS. PART 2. D. L. Schmidt. (Modern Plastics, Vol. 38, No. 4, December 1960, pp. 147-154+)

343. LUBRICATION IN SPACE ENVIRONMENTS. R.L. Adamczak, R.J. Benzing and H. Schwenker. Nonmetallic Materials Laboratory. Aeronautical Systems Division. (National Symposuim on The Effects of Space Environment on Materials, St. Louis, Missouri, 7-9 May 1962 12 p.)

Solid, semi-solid and liquid lubricants, hydraulic fluids, heat transfer fluids and novel lubrication techniques are discussed with respect to the current "State of the Art" and the future capabilities of these various materials and/or their application. The severe environmental conditions of space are compared against both the current and future "State of the Art" in the field of lubrication and energy transfer media. Research efforts currently being pursued by the Nonmetallic Materials Laboratory of ASD to provide new and improved lubricants are described. A brief interpolation is also given of the overall lubricant picture with respect to space technology in terms of reliability and system design.

344. FLUOROCARBON PLASTICS UNDER THE INFLUENCE OF UNUSUAL ENVIRONMENTAL CONDITIONS. Robert P. Bringer, Minnesota Mining and Manufacturing Company. (National Symposuim on The Effects of Space Environment on Materials, St. Louis, Missouri, 7-9 May 1962, 22 p., 14 refs.)

The fluorocarbon plastics, already known for their chemical inertness and temperature resistance, are reviewed in light of available data taken under exposure to unusual conditions. The introductory section includes a brief description of the chemical nature and general properties of the commercially important fluorocarbon plastics. The remainder of the paper is devoted to exploring the effects of high and low (cryogenic) temperatures, exposure to liquid oxygen, $\gamma$- and x-irradiation in air and in vacuum, ultraviolet radiation, and vacuum exposure.

345. MATERIALS IN SPACE. R. A. Happe. (Ordnance, Vol. 45, No. 244, January 1961, pp. 578-580)

346. ADVANCES IN SPACE TECHNOLOGY. VOLUME 2. Frederick I. Ordway, III, Editor. (Academic Press, New York, 1960, 450 p.)

Contents include an article entitled, "Materials in space," by Frederick L. Bagby.

347. SPACE VEHICLE ENVIRONMENT. C. Gazley, Jr., W. W. Kellogg and E. H. Vestine. (Rand Corporation, Report P-1335 Revised, 15 June 1959, 58 p.)

Effects of solar and other thermal radiations on vehicle temperature, the characteristics of the earth's magnetic fields and other magnetic fields in space, the earth's exosphere and the solar corona, cosmic rays, and meteoroids. Estimates of the probability of vehicle skin penetration by meteoroids.

348. EFFECTS OF A SIMULATED SPACE ENVIRONMENT ON THE PROPERTIES OF ELASTOMERS. Z. T. Ossefort and J. D. Ruby. (Rock Island Arsenal Laboratory, Illinois, 61-1999, 15 May 1961)

The exposure of elastomers to the following conditions is discussed: (1) extremely high vacuum, (2) high and low temperatures, (3) actinic solar radiation, (4) cosmic radiation, undiminished by atmospheric penetration, and (5) particle bombardment from tiny meteorites.

349. EXPERIMENTS FOR MEASURING TEMPERATURE, METEOR PENETRATION, AND SURFACE EROSION OF A SATELLITE VEHICLE. Herman E. LaGow, U. S. Naval Research Laboratory, Washington, D. C. (Scientific Uses of Earth Satellites, James A. Van Allen, Editor, University of Michigan Press, Ann Arbor, 1958, pp. 68-72, 4 refs.)

Satellite experimentation represents a tremendous step from rocket instrumentation. It offers obvious advantages in studying variations in physical quantities in time and latitude and perhaps even altitude. However, there are several evident disadvantages. The chief disadvantage is the limited payload. Not only does the instrumentation have to be two orders of magnitude lighter than rocket instruments, but it must last for from one to five orders of magnitude longer. This means that the instrumentation must be miniaturized to the limit. To do this reliably, one must know the environment in which the instrumentation is required to operate. Some of the environmental conditions can be estimated from theory and rocket soundings, but others must be evaluated from measurements on the satellite. Plans are described for measuring temperature extremes, surface erosion, and surface penetration.

350. EFFECTS OF THE EARTH'S IONOSPHERE ON HF RADIO ASTRONOMY FROM ARTIFICIAL SATELLITES. M. D. Grossi, K. M. Strom and S. E. Strom. (Smithsonian Institution, Astrophysical Observatory, Cambridge, Massachusetts, Special Report No. 76, 2 October 1961, 16 p.) AD-264 900

An analysis was made of some effects of the ionosphere on HF observations from satellite-borne radio telescopes. A search was conducted for focusing effects of the ionosphere on incoming cosmic noise in the HF band. The analysis covers a variety of cases, of interest for satellites in various orbital altitudes and with a wide range of observation frequencies. In this preliminary analysis, the ionosphere was considered to be a non-homogeneous, nonisotropic, magnetoionic medium. The electron-density profile in the calculations is illustrated. The earth's magnetic field was assumed to be dipole in nature. Ionospheric irregularities and discontinuities only for cases in which these disturbances are much larger in size than are the wavelengths considered. The effects of the ionosphere on incoming radiation was computed by employing a Hamiltonian optics approach. The necessary numerical procedures involved in the ray-tracing in relation to a program suitable for use in an IBM-7090 computer are discussed. Rays were computed and plotted for sources located at infinity and frequencies in the band 1-30 mc.

351. STATE OF THE ART--MATERIALS. (Space/Aeronautics, Vol 38, No. 2, pp. H-3-H-14, 92 refs.)

Review of the status of materials, covering (1) environments (including hard vacuum of space, cryogenics, and nuclear system materials); (2) Composite systems (including "matrix materials", glass fibers, reinforcements, and chromium composites); (3) iron base alloys, steels, and super-alloys (including mar-aging 18-25Ni iron base alloys and nickel-base super-alloys); (4) refractory alloys and beryllium (including tungsten-thorium, tungsten-molybdenum, columbium, and molybdenum); (5) nonferrous metals (including magnesium-lithium, aluminum, and rare-earth metals); (6) plastics (including high-temperature organics); (7) ceramics (including borides, nitrides, silicides, beryllium oxide, high-temperature ceramics, and intermetallics); and, hydraulic fluids, lubricants, and elastomers.

352. EQUIPMENT DESIGN CONSIDERATIONS FOR SPACE ENVIRONMENT. S. N. Lehr, L. J. Martire and V. J. Tronolone. (Space Technology Laboratories, Inc., Redondo Beach, California, Report TR-9990-6032-RU000, February 1962, 122 p., 145 refs.)

Information compiled from a literature survey and from STL experience is presented in this document as an aid to the design and fabrication of electronic equipment for space vehicles. Data are presented concerning the behavior of materials in space, covering information not available in the usual engineering handbooks.

Space environment is considered in terms of temperature, high vacuum, micrometeorites, radiation, and other phenomena, with particular attention to the effects of such environment, insofar as they are known or conjectured, upon plastics, organic and inorganic materials, metals, and upon electronic parts.

353. SURVEY OF THE PHYSICAL ENVIRONMENTS OF BOOST-GLIDE AND SATELLITE VEHICLE ELECTRONIC EQUIPMENT. Roger L. Sullivan and Walter Curley. (Sylvania Electric Products, Inc., Waltham, Massachusetts, Contract AF 33(616)-6309, Technical Report No. 440-1, 29 April 1960, 1 Vol., 157 refs.) AD 241 648

The physical environment of manned boost-glide vehicles and unmanned satellite vehicles was studied. In particular, it is a study of the environment which low wattage, solid state electronic equipment will be expected to withstand when operating within the vehicle and during test, transit and storage. Both induced and natural environments are covered. The induced environments which are reviewed are temperature, vibration, acoustic noise, mechanical shock, acceleration and explosive atmospheres. The natural environments included are moisture forms, fungus, sand and dust, pressure, altitude, electrostatic fields, and radiation. The environments are listed which may possibly have a detrimental effect on the operation of the electronic equipment in these vehicles with best known numerical values.

354. CONFERENCE ON BEHAVIOR OF PLASTICS IN ADVANCED FLIGHT VEHICLE ENVIRONMENTS. H. S. Schwartz, Materials Central. (U. S. Air Force, Wright Air Development Division, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, WADD Technical Report 60-101, September 1960, 460 p.)

This report is the collection of papers presented at the Materials Central, WADD conference on "Behavior of Plastics in Advanced Flight Vehicle Environments" held in Dayton, Ohio on 16-17 February 1960.

The purpose of this conference was to review the recent progress in studies on plastics exposed to severe thermal environments and simulated extremely high altitude environments. The papers presented are primarily on internal and contractual programs sponsored by the Plastics Branch of the Nonmetallic Materials Laboratory. Papers on work performed by other organizations in the Department of Defense and by their contractors were also presented and are included.

355. EFFECTS OF SIMULATED SPACE ENVIRONMENTS ON CUSHIONING MATERIALS. D. N. Keast and J. J. Baruch, Bolt Beranek and Newman, Inc., Cambridge, Massachusetts. (Wright Air Development Division, Materials Laboratory, Wright-Patterson Air Force Base, Ohio, WADC TR 58-667) AD-229 932

Measurements of some of the properties of several types of package cushioning materials at temperatures of +75$^{\circ}$F, -65$^{\circ}$F, and -200$^{\circ}$F and pressures of 760 and $10^{-4}$ mm Hg have been performed. Static and dynamic stress-strain curves and vibration transmissibility characteristics have been obtained for glass fiber, latex bound hair, polyurethane foam, silicone rubber foam, and crushable paper honeycomb materials. The data are presented and briefly discussed, and the instrumentation necessary for the performance of the measurements is described.

356. EFFECTS OF SPACE ENVIRONMENT ON MATERIALS. J. H. Atkins, R. L. Bisplinghoff, J. L. Ham, E. G. Jackson and J. C. Simons, National Research Corporation, Cambridge, Massachusetts. (Wright Air Development Division, Wright-Patterson Air Force Base, Ohio, WADD TR 60-721, December 1960)

This report is a general survey of the current knowledge of the major factors influencing space environment, such as radiation, high vacuum and meteoroids; the effects of these factors on materials; and the problem of simulating these conditions in the laboratory.

357. BREAKTHROUGH INTO SPACE. V. Parfonov. (Znaniye - Sila, Vol. 10, October 1960, pp 1-3) also (Air Force Systems Command, Foreign Technical Division, Wright-Patterson Air Force Base, Ohio, Translation No. MCL-1185/1, 8 August 1961, 17 p.) AD 269 630

The materials for the body of the spaceship should protect the crew from the cosmic vacuum, withstand erosion when the skin is bombarded by cosmic dust, and withstand the impacts of small meteorites. A group of very refractory metals which must be heated to 3000 degrees and higher to be melted include Be, Nb, Mo, Ta, and W. The properties of these metals are discussed.

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